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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 116.
L. O. HOWARD, Entomologist and Chief of Bureau.

PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

I. SPRAYING EXPERIMENTS AGAINST THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY IN 1911.
By FRED JOHNSON, *Agent and Expert.*

II. THE GRAPE-BERRY MOTH.
By FRED JOHNSON and A. G. HAMMAR, *Entomological Assistants.*

III. THE CHERRY FRUIT SAWFLY.
By S. W. FOSTER, *Entomological Assistant.*

IV. LIME SULPHUR AS A STOMACH POISON FOR INSECTS.
By E. W. SCOTT and E. H. SIEGLER, *Entomological Assistants, Deciduous Fruit Insect Investigations.*

V. THE FRUIT-TREE LEAF-ROLLER.
By JOHN B. GILL, *Entomological Assistant.*

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L. O. HOWARD, *Entomologist and Chief of Bureau.*
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DECIDUOUS FRUIT INSECT INVESTIGATIONS.

A. L. QUAINTANCE, *In Charge.*

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E. W. SCOTT, W. S. ABBOTT, J. E. DUDLEY, JR., *employed in enforcement of Insecticide Act of 1910.*

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

SPRAYING EXPERIMENTS AGAINST THE GRAPE LEAFHOPPER IN THE LAKE ERIE VALLEY IN 1911.

By Fred Johnson,
Agent and Expert.

INTRODUCTION.

An insect pest of the grapevine which has increased in abundance and destructiveness in the vineyards of the Lake Erie Valley during the past few years is the grape leafhopper, *Typhlocyba comes* Say (see fig. 1). Preliminary spraying experiments were undertaken against this pest at North East, Pa., by the Bureau of Entomology in 1910. Results of the field work undertaken during that season are presented in Bulletin No. 97, Part I, of the Bureau of Entomology, together with a brief consideration of the characteristics, habits, and life history of the insect, and also the character and extent of its injury to the vine. For this reason the subject matter of this paper deals entirely with experiments conducted during the season of 1911. Readers unfamiliar with the habits of this pest should consult the paper referred to above.

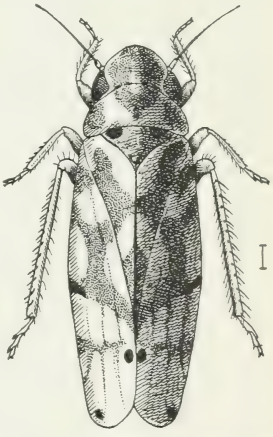

Fig. 1.—The grape leafhopper (*Typhlocyba comes* var. *coloradensis*): Adult. Greatly enlarged. (Author's illustration.)

TREATMENT OF NYMPHS OF THE GRAPE LEAFHOPPER WITH CONTACT SPRAYS.

During the season of 1911 the grape leafhopper was more numerous and destructive to the grapevines in the vineyards of Erie County, Pa., than in 1910. Owing, doubtless, to the higher temperatures prevailing during June and July of this season, the nymphs (see fig. 2) commenced to appear on the leaves at an earlier date, and the development of the nymphal stages of the insect were more rapid than in 1910. Since it is in this the nymphal period before the insect has developed

wings (figs. 2–3) that it is most readily controlled by a contact spray, it was necessary to make the application several days earlier than in the preceding season. In addition to this, the number of days when the maximum number of nymphs was present upon the vines before the earliest to hatch had developed wings was materially lessened, thus shortening the period during which the greatest efficiency from the spray applications could be secured. In 1910 the maximum numbers of nymphs of the first brood were present on the underside of the grape leaves about July 15 and spray applications were commenced at that date and were continued until July 26 before many of the nymphs had changed to adults having fully developed wings.

FIG. 2.—The grape leafhopper: Nymph of the first stage. Greatly enlarged. (Author's illustration.)

In 1911, however, the maximum numbers of nymphs were present on the leaves by July 5. By July 11 fully 15 per cent of the first nymphs to hatch were changed to the winged form. Thus there was about a week longer time during which the greatest efficiency from the spray application could be secured in the season of 1910 than in 1911. Effective work can be done, however, after many of the nymphs have developed wings, and if the wingless nymphs are still quite numerous upon the leaves the work may be continued with good results. Owing to the more rapid development of the immature stages of the insect in 1911 than in 1910, there was a partial second brood of considerable proportions in 1911, which greatly augmented the injury toward the ripening season. Nevertheless, where vines were thoroughly sprayed against the nymphs of the first brood during the first two weeks in July, only slight injury resulted from the later development of nymphs on these sprayed vines.

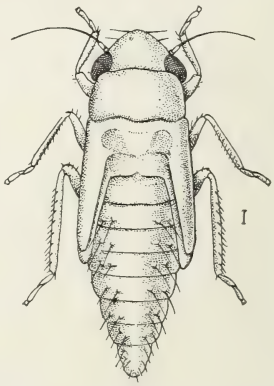

FIG. 3.—The grape leafhopper: Fully developed nymph of the fifth stage. Greatly enlarged. (Author's illustration.)

FIELD EXPERIMENTS WITH TOBACCO EXTRACTS.

During the summer of 1911 several field experiments, in each case covering several acres, were conducted in vineyards in the township of North East, Pa. In all cases the applications were made against the nymphs about the time the maximum number of the first brood was present on the underside of the grape leaves and before many of the oldest nymphs had changed to the winged form. One thorough application at this time proved sufficient to reduce the

number of the insects so that those remaining did not materially affect the growth of the vine or the proper ripening of the fruit.

These experiments were conducted in different parts of the township and several types of sprayers were used in making the applications. In all cases the "trailer" method was employed; that is, a trailing hose about 20 feet long was connected to the discharge of the spray pump and a short rod, about 2½ feet long, carrying a large nozzle of the cyclone type set at right angles to the rod was attached to the free end of this lead of hose. This rod is held by the operator, who thrusts the nozzle among the foliage with rapid movements, directing the nozzle upward, so that the liquid is thrown upon the underside of the leaves. (See Pl. I, fig. 1.)

Two forms of commercial tobacco extract were used in these experiments: No. I (blackleaf extract) contained 2.70 per cent nicotine; No. II (blackleaf 40) contained 40 per cent nicotine sulphate. In all of the experiments which follow the tobacco extracts are referred to by number. Tobacco extract No. I refers to the form containing the lower percentage of nicotine, tobacco extract No. II to the form containing the higher percentage of nicotine. At the dilutions used no decided advantage was evidenced in favor of either form of tobacco extract. Both of these substances killed the nymphs that were hit by the spray. The tobacco extract No. I at a dilution of 1 part of extract to 150 parts of water killed all nymphs that were made thoroughly wet by the spray, especially the smaller nymphs, between the first and fourth molts. The full-grown nymphs, unless thoroughly soaked by the spray at this dilution, would sometimes escape, probably because their longer legs held their bodies some distance from the wet surface of the leaf. The tobacco extract No. II was effective at a dilution of 1 part of extract to 1,500 parts of water. In the use of the tobacco extract No. II—as with the tobacco extract No. I, where a large percentage of the nymphs were in the last stage; that is, just about to develop wings (see fig. 3)—a dilution of 1 to 1,200 or 1,300 may be more effective in killing the nymphs. In the several experiments conducted, however, the dilutions varied from 1 to 100 parts of water to 1 to 150 with tobacco extract No. I, and from 1 to 1,000 to 1 to 1,500 with tobacco extract No. II. In all of these variations of dilution apparently equally good results were obtained.

VINEYARD EXPERIMENTS IN 1911.

EXPERIMENT IN VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA.

The east side of the vineyard of Mr. H. H. Harper, North East, Pa., adjoining the highway had been badly infested by the grape leafhopper for several years. Previous to the undertaking of this experiment

the vines had each season made a weaker growth as a result of injury by this pest, and the yield of fruit also was being greatly reduced.

During the season of 1910 several acres on the east side of this vineyard were sprayed with tobacco extract No. I. This treatment resulted in preventing serious injury by the insect. The foliage remained green and healthy throughout the season. There was a greatly increased growth of vine and a higher quality of fruit was secured. The greatest apparent benefit in 1910 was in the great increase in growth of vine.

During the season of 1911 the entire vineyard of 25 acres was sprayed against this pest, which was present in fully as large numbers as in 1910.

A tractor sprayer was used in making the application. (See Pl. I, fig. 1.) A pressure of 100 to 140 pounds was maintained and about 175 gallons of liquid were applied per acre. The application was made by the owner of the vineyard, Mr. H. H. Harper. The spray was applied by the "trailer" method (see Pl. I, fig. 1), using a single large cyclone nozzle. The work was done very carefully and thoroughly. Stops were made at each vine. The pressure was maintained by driving forward the length of the trailer hose. By having a 20-gallon air-chamber on the tractor sprayer a pressure varying from 100 to 140 pounds was secured, rarely dropping below the 100-pound mark. Under favorable working conditions about 3 acres could be covered per day. The tobacco extract No. I was applied at a dilution of 3 quarts to 100 gallons of water. The application was made, on the 3 acres from which our record of yield was secured, on July 6 and 7, when the majority of the nymphs were small but very numerous. The application was very effective, and on account of the thoroughness with which the work was done only a very small percentage of nymphs escaped being killed by the spray.

As a result of this treatment the foliage of the vines remained green throughout the entire season, and the vines made a very heavy growth of new canes. The berries and clusters of fruit were large and of good quality. A record has been kept of the yield for the past three years on 3 acres of this vineyard where the injury by this insect was most apparent at the beginning of the experiment. No attempt to control this pest on these vines was made previous to 1910.

1909.....Yield of fruit was 262 8-pound baskets of grapes per acre.
1910.....Yield of fruit was 423 8-pound baskets of grapes per acre.
1911.....Yield of fruit was 796 8-pound baskets of grapes per acre.

These results show an increase in yield on the first season's treatment of 161 baskets per acre, and for the second season's treatment an increase of 534 baskets per acre over the yield of 1909.

Since the price received per basket of grapes varies each season, it is difficult to compare cash returns one season with another. Prices

FIG. 1.—ROD AND SINGLE CYCLONE NOZZLE USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY TRACTOR SPRAYER. VINEYARD OF MR. H. H. HARPER, NORTH EAST, PA. (ORIGINAL.)

FIG. 2.—ROD CARRYING TWO CYCLONE NOZZLES USED TO APPLY SPRAY TO UNDERSIDE OF GRAPE FOLIAGE. POWER SUPPLIED BY COMPRESSED AIR. VINEYARD OF MR. A. I. LOOP, NORTH EAST, PA. (ORIGINAL.)

for the past 10 years, however, have averaged about 13 cents per basket. On this basis the cash increase on the treatment in 1910 was $20.93 per acre, and on the treatment for the second season of 1911 the increase was $69.42 over that of 1909 before any spray treatment was made against this pest.

The actual cash receipts for the three seasons were as follows:

1909	Unsprayed,	11 cents per basket,	262 baskets, $28.82 per acre.
1910	Sprayed,	19 cents per basket,	423 baskets, $80.37 per acre.
1911	Sprayed,	10 cents per basket,	796 baskets, $79.60 per acre.

Since the actual prices in 1909 and 1911 are almost uniform, the increase in cash return as a result of increased yield is readily seen. This increased cash return in 1911 was $50.78 per acre.

During these three seasons the general treatment for the vineyard has been the same for each season. The soil was cultivated several times and 420 pounds of fertilizer containing 5 per cent nitrogen, 8 per cent phosphoric acid, and 8 per cent potash were applied each season. A Bordeaux and arsenate of lead spray application, consisting of 4 pounds of copper sulphate, 5 pounds lime, and 3 pounds arsenate of lead to 50 gallons of water, was made just after blossoming. A later application of 1 pound of copper sulphate to 100 gallons of water was made for protection against mildew. Thus the general treatment of the vineyard was good and conducive to the securing of maximum results.

The additional cost of material and labor involved in making the spray application against the grape leafhopper was as follows:

Cost of team per day		$2.25
Boy to drive		1.00
Man to handle nozzle		1.75
Tobacco extract No. I (strength 3 quarts to 100 gallons of water, applied 175 gallons per acre)	per gallon..	.85
Cost of material for 3 acres		3.36
Total cost of spraying 3 acres per day		8.36
Total cost of spraying 1 acre		2.79

The power was supplied by a tractor sprayer.

There is no doubt that this tobacco-extract application during the past two seasons has effectively controlled the grape leafhopper and is largely responsible for the increase in crop yield and for the vigorous growth of vine in this vineyard.

EXPERIMENT IN VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA.

The vines in the vineyard of Mr. W. E. Gray, North East, Pa., were badly infested by grape leafhoppers. They were five years old and were bearing a heavy crop of fruit. No spray treatment was given them except with tobacco extract No. I for this pest. About

6 acres were sprayed with tobacco extract No. I. An acre was left unsprayed in the middle of this block.

A gasoline-engine sprayer outfit was used to make the application. The "trailer" method of application was employed.

About 15 per cent of the nymphs of the first brood had developed wings when this spray application was made, July 11 and 12. Nearly all of the nymphs were about full grown and it was thought desirable to use a stronger dilution than in the foregoing experiment. The tobacco extract No. I was used at a dilution of 1 gallon to 100 gallons of water. A pressure of about 125 pounds was maintained throughout. Two leads of hose were used and about 275 gallons of liquid were applied per acre.

Within about three weeks after the application was made the difference in injury on the sprayed and unsprayed grape leaves became noticeable. Upon the unsprayed vines the winged adult "hoppers" were very numerous and the leaves were commencing to turn brown and only a small amount of new growth was being made.

Upon the sprayed vines, on the other hand, the number of winged adults was noticeably much smaller, the foliage was dark green and healthy, and the new growth of vine was quite thrifty throughout the growing season. When the fruit commenced to ripen it became quite evident that the berries and the clusters would be smaller and the fruit not so purple in color upon the unsprayed vines as upon those that were sprayed. Plate II, figure 1, shows a vine in the unsprayed plat. Plate II, figure 2, shows a vine in the sprayed plat. When the crop was harvested the sprayed plat yielded 128 baskets of grapes per acre more than the unsprayed plat. This fruit was sold at 10 cents per basket, giving a gross cash gain of $12.80 per acre. The cost of spray material and labor of making the application against this pest was as follows:

Team and driver per day	$4.50
Two men to apply spray, $1.75 per day	3.50
Tobacco extract No. I, 275 gallons per acre	2.33
Six acres sprayed per day, cost per acre	3.66
Increased cash yield per acre, sprayed plat	12.80
Cost of material and application per acre	3.66
Cash increase per acre on sprayed vines	9.14

Thus the net yield on the sprayed plat after deducting all expense of labor and material was $9.14 per acre. In addition to this increase in crop yield the sprayed vines made a more vigorous and healthy growth than did the unsprayed vines, and the fruit was of much better quality.

EXPERIMENT IN VINEYARD OF MR. J. E. BEATTY, NORTH EAST, PA.

The vineyard of Mr. J. E. Beatty, North East, Pa., had been badly infested by grape leafhoppers for several years. As a result of their injury the cane growth of the vines had been greatly reduced and there had been a corresponding reduction in yield of fruit. Thirteen acres of the worst infested sections of this vineyard were sprayed in 1911. Unfortunately, the spraying was not commenced until about 15 per cent of the first nymphs to hatch had changed to the winged form. The application was made July 12 and 14, using a gasoline-engine power-spraying outfit with two "trailer" leads of hose (see Pl. III, fig. 1). A pressure of 175 pounds was maintained and about 250 gallons of liquid were applied per acre. Tobacco extract No. I was used at a dilution of 1 part to 150 parts of water. This dilution gave good results, even though a large percentage of the nymphs was in the last molt. Within about three weeks after the application was made the foliage of the unsprayed vines commenced to turn brown, and as the season advanced new growth at the end of the canes ceased, whereas on the sprayed vines the foliage remained green and the new growth continued to develop until late in the season. The berries were larger and a darker purple in color upon the sprayed vines. When the crop was harvested the fruit from 300 vines in the unsprayed plat and from the same number of vines on the sprayed plat was weighed and showed a gain of 690 pounds from the sprayed plat, thus giving an increase of 1,380 pounds per acre. This fruit was valued at $0.015 per pound, showing a gross cash gain of $20.70 per acre. The cost of spray material and labor of application was as follows:

Team and driver per day	$4.50
250 gallons of tobacco extract No. I, diluted spray	1.41
Two men handling nozzles	3.50
Six acres sprayed per day, cost per acre	2.74
Increased cash yield per acre	20.70
Cost of material and application	2.74
Net cash gain per acre on sprayed vines	17.96

EXPERIMENT IN VINEYARD OF MR. D. C. BOSTWICK, NORTH EAST, PA.

The grape leafhopper was very numerous in the vineyard of Mr. D. C. Bostwick, North East, Pa., during the summer of 1911. The experiment was undertaken on a block of young vines in the second year of bearing. The vines in this block were quite uniform and carried a heavy crop of fruit. About 15 per cent of the nymphs had transformed to adults when the spray application was made. The spray was applied from July 13 to 15. Three acres were taken in about the middle of the block. One acre on each side of the untreated

acre was sprayed. The work was done with a tractor vineyard sprayer. This machine had been in use several seasons and was not working at its best. The spray was applied by the "trailer" method. Owing to the poor working of the pump a high pressure was not maintained. The pressure varied anywhere from 150 pounds to 50 pounds. Most of the time it ran below 80 pounds. For this reason it was thought necessary by Mr. Bostwick to make the application on both sides of the trellis. In spite of these drawbacks good results were secured. About 275 gallons of liquid were applied per acre. This is more liquid than would have been applied by this machine had it been in good working condition and, in addition, more time was consumed in making the application on both sides of the row. About 600 gallons of spray were applied per day covering about 2¼ acres. Tobacco extract No. II was used at a dilution of 1 to 1,300 parts of water.

Labor cost of application per acre	$2.75
Tobacco extract No. II—1 to 1,300 parts water, per acre	2.58
Total cost of labor and material per acre	5.33

The net yield of grapes from the three plats was as follows:

One acre of vines east of unsprayed plat	8,462 pounds grapes
One acre of vines west of unsprayed plat	8,327 pounds grapes
One acre of vines, unsprayed plat	7,153 pounds grapes

The cash value of the fruit was $25 per ton, or $0.0125 per pound.

Cash value of yield on 1 acre east of check	$105.77
Cash value of yield on 1 acre west of check	104.09
Cash value of yield on 1 acre unsprayed	89.41
Increased yield on west plat per acre over check was 1,309 pounds, or	16.36
Increased yield on west plat per acre over check was 1,174 pounds, or	14.67

Net cash gain on sprayed plats after deducting cost of labor and material:

Gross gain on plat west of check per acre	$16.36
Total cost of labor and material per acre	5.33
Net gain resulting from spraying per acre	11.03
Gross gain on plat east of check per acre	14.67
Total cost of labor and material per acre	5.33
Net cash gain resulting from spraying per acre	9.34

In addition to this increase in weight of fruit yield it was observed that the berries of the grapes were much larger and of better color than was the fruit on the unsprayed vines. It was also observed that the fruit from the sprayed vines gave a greater weight per basket.

507 baskets from the west plat averaged 20.7 pounds per basket.
497 baskets from the east plat averaged 20.7 pounds per basket.
478 baskets from the unsprayed plat averaged 19 pounds per basket.

FIG. 1.—SHOWING CONDITION OF VINE INJURED BY THE GRAPE LEAFHOPPER IN THE UNSPRAYED PLAT. NOTE LOSS OF FOLIAGE, AND ALSO THE BERRIES FROM THE CLUSTERS. VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA. (ORIGINAL.)

FIG. 2.—SHOWING CONDITION OF VINE IN PLAT SPRAYED WITH TOBACCO EXTRACT NO. 1, AGAINST THE GRAPE LEAFHOPPER. NOTE THE LARGER SIZE OF THE BERRIES IN THE CLUSTERS, HEAVY FOLIAGE AND STRONGER CANE GROWTH. VINEYARD OF MR. W. E. GRAY, NORTH EAST, PA. (ORIGINAL.)

COMPARISON OF SPRAYED AND UNSPRAYED PLATS.

FIG. 1.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE, IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF MR. J. E. BEATTY, NORTH EAST PA. (ORIGINAL.)

FIG. 2.—GASOLINE-ENGINE SPRAYER SUPPLYING POWER FOR TWO "TRAILER" LEADS OF HOSE IN SPRAYING AGAINST THE GRAPE LEAFHOPPER. VINEYARD OF THE PEACOCK-ROOD COMPANY, WESTFIELD, N. Y. (ORIGINAL.)

SPRAYING AGAINST THE GRAPE LEAFHOPPER.

This shows an average increase in weight of 1.7 pounds per basket for fruit from the sprayed vines. As in the case of all the other experiments, the foliage on the sprayed vines remained green and healthy throughout the season, and new growth of canes continued to be made for a longer period than upon the unsprayed vines.

USE OF COMBINED CONTACT AND POISON SPRAY.

In addition to the experiments described, in which the spray ingredients consisted of either tobacco extract No. I and water or tobacco extract No. II and water, other experiments were made, in one case adding the tobacco extract No. II to Bordeaux mixture and fish-oil soap. In this experiment about two-thirds of an acre of the infested vines was sprayed with the Bordeaux, fish-oil soap, and tobacco extract No. II mixture, and about one-third of an acre was sprayed with tobacco extract No. II and water. So far as could be observed the killing effect of tobacco extract No. II upon the nymphs when mixed with the Bordeaux and soap was in no way lessened; nor was any injurious effect apparent to the leaves and fruit of the vines sprayed with this mixture. The ingredients were used in this mixture at the following dilution: Bordeaux mixture, 3 pounds lime, 3 pounds copper sulphate to 50 gallons of water, plus 2 pounds of fish-oil soap, and tobacco extract No. II at a dilution of 1 to 1,500 parts of the Bordeaux mixture. Tobacco extract No. II at a dilution of 1 to 1,500 parts water.

In another experiment 5 acres of vineyards were sprayed with a mixture of Bordeaux, arsenate of lead, and tobacco extract No. I, at the following dilution, 3 pounds of lime, 3 pounds of copper sulphate, 2 pounds arsenate of lead to 50 gallons of water plus tobacco extract No. I, 1 to 150 parts of the Bordeaux mixture. So far as could be observed the killing effect of the tobacco extract upon the nymphs was not lessened in this mixture nor were any injurious effects from this mixture observed upon the foliage and fruit of the vines. The object of adding the tobacco ingredient to the Bordeaux and the arsenate of lead mixtures is an endeavor to reduce the number of applications made necessary in some instances to control the several insect and fungous enemies attacking the foliage or the fruit of the grapevine. The advisability of applying the tobacco extracts against the grape leafhopper with Bordeaux and arsenate of lead will be a matter for the individual vineyardist to decide after he has made a thorough examination of his vineyard to determine if other insects are present in numbers sufficient to warrant their treatment. The insects which may possibly be infesting the foliage or fruit of the grape at the time of treating the nymphs of the grape leafhopper with the tobacco extracts are the grape rootworm and the grape berry moth.

The second poison application against the grape rootworm to the surface of the leaves of the grape is usually made during the first two

weeks in July. At this time also larvæ of the grapeberry moth are hatching from eggs deposited upon the grape berries. Since it is impossible to cover thoroughly the underside of the grape leaves in spraying for the grape leafhopper without thoroughly wetting the grape clusters it is reasonable to infer that the addition of arsenate of lead would also assist in checking the injury to the grape berries by the larvæ of the grape berry moth. In addition to this the Bordeaux mixture will control the development of mildew on the stems of the grape clusters. The upper surface of the grape leaves also is covered during this process (see Pl. III, fig. 2); hence, if arsenate of lead is present with the tobacco extract this application will control the late emerging beetles of the grape rootworm. As intimated above, the advisability of making this combination of ingredients must be decided by the prevalence and abundance in the vineyard to be treated of the several insects referred to. It should also be borne in mind that this combination treatment is submitted as a suggestion.

The mixing of the tobacco extracts with Bordeaux and arsenate of lead this season was done for the sole purpose of determining if this mixture would be injurious to the grape foliage and berries. As mentioned above, no injurious effect to the vine was observed. Arsenate of lead is the only arsenical that should be used with tobacco extracts, since both arsenite of lime and Paris green cause serious burning of the foliage when mixed with the tobacco extracts.

EFFECT OF GRAPE LEAFHOPPER CONTROL ON QUALITY OF FRUIT

As mentioned in foregoing paragraphs dealing with results secured in these spraying experiments with tobacco extracts, it was observed that in every case where the nymphs were successfully controlled the berries of the grape clusters from these vines were much larger, a darker purple in color, and much sweeter than the fruit from unsprayed vines in the same vineyard. In order to ascertain if there was any marked difference in the sugar content of the grapes from vines growing in the sprayed and unsprayed plats samples representing the average condition of the fruit from sprayed and unsprayed vines from experimental plats in the vineyards of Mr. J. E. Beatty and Mr. W. E. Gray, North East, Pa., were submitted for analysis.

These samples of grapes taken for analysis were forwarded to Prof. Wm. B. Alwood, in charge of Enological Investigations at the laboratory of the Bureau of Chemistry located at Sandusky, Ohio. The samples were there analyzed in connection with the extended studies that Prof. Alwood is making of the chemistry of many varieties of grapes grown in the eastern United States in relation to wine production.

The report received from Prof. Alwood on these samples of grapes from these sprayed and unsprayed experimental plats is given in Table I.

TABLE I.—*Analysis of grapes from sprayed and unsprayed grapevines in vineyards of Mr. W. E. Gray and Mr. J. E. Beatty, North East, Pa., in experiments with tobacco extract No. I against nymphs of grape leafhopper. Analysis made at laboratory of United States Bureau of Chemistry under direction of Prof. Wm. B. Alwood.*

Serial No.	Variety, grower, locality.	Field number.	Date collected.	Brix at 20° C.	Specific gravity.	Grams per 100 c. c.				Tartaric acid as tartrates.	Condition of fruit and spray treatment, tobacco extract No. I.
						Total solids.	Sugar-free solids.	Total sugar as reducing.	Total acid as tartaric.		
3153	Concord, W. E. Gray, North East, Pa.	123	Sept. 20, 1911	17.7	1.0726	18.84	2.66	16.18	0.720	0.549	Medium bunches, good condition, fully ripe. Vines sprayed against grape leafhopper.
3154	.....do.....	124	.....do.....	11.0	1.0445	11.52	2.91	8.61	.938	.612	Bunches small, berries somewhat dried, reddish color, condition poor. Vines not sprayed against grape leafhopper.
3155	J. E. Beatty, North East, Pa.	125	Sept. 21, 1911	18.7	1.0777	20.18	3.00	17.18	.720	.540	Fine bunches, grapes large and in good condition, fully ripe. Vines sprayed against grape leafhopper.
3156	.....do.....	126	.....do.....	14.5	1.0576	14.93	2.41	12.52	.720	.583	Bunches fair, small uneven berries, poor quality, fully ripe. Vines not sprayed against grape leafhopper.
3261	W. E. Gray, North East, Pa.	236	Oct. 11, 1911	18.4	1.0772	20.05	1.71	18.34	.450	.369	Bunches and berries large, good condition, fully ripe. Vines sprayed against grape leafhopper.
3260	.....do.....	235	.....do.....	13.1	1.0534	13.83	1.86	11.97	.536	.494	Bunches and berries small, poor sample. Vines not sprayed against grape leafhopper.

In comparing the sugar content of the samples from the sprayed and the unsprayed plats it will be observed that the sample from the unsprayed plat under serial No. 3154 showed a sugar content of only 8.61 grams per 100 c. c. as against 16.18 grams per 100 c. c. for sample 3153 from the sprayed plat. In other words, the sample of grapes taken from the plat where the injury to the foliage of the vines by the grape leafhopper was unchecked, by withholding the tobacco-extract spray against the nymphs, contained only about one-half the sugar content that was present in the sample taken from the vines which were sprayed with the tobacco against this insect in the nymphal stage. Samples under serial No. 3156 from the unsprayed plat show a sugar content of 4.66 grams per 100 c. c. less than sample No. 3155, taken from the sprayed plat, and sample No. 3260 from unsprayed plat shows a sugar content of 6.37 grams per 100 c. c. less than sample 3261, taken from sprayed vines in the same vineyard.

In answer to an inquiry as to the approximate difference in value of the fruit from these sprayed and unsprayed plats for use in making wine or grape juice Prof. Alwood gives the following reply:

> In response to your question I may say that the sugar content of the three untreated plats is so low that they would have no value whatever for making pure wine or unfermented grape juice and could only be used for some low grade sophisticated products.

Thus the analysis of these samples of fruit indicates that serious injury to the foliage of the grapevine by the grape leafhopper greatly impairs the quality of the fruit. A definite knowledge of this fact furnishes an additional reason why the vineyardist should resort to every practical means at his disposal for the control of this insect whenever it is at all numerous in his vineyard.

CONCLUSION.

The field experiments made during the season of 1911 against the grape leafhopper and recorded in this paper show that a single application of the tobacco extracts applied against this insect in the nymphal stage as a contact spray will reduce its numbers to such an extent that the infested vines will remain in good foliage throughout the season and mature a crop of high-quality fruit.

As indicated by the variation in the time and rapidity in development of the nymphs in 1910 and 1911, it is evident that no definite date for making the spray application can be given. Where the winged adults are at all numerous in the early part of the season the vineyardist is urged to examine the underside of the grape leaves toward the middle and the end of June and to observe the number and size of the nymphs. The spray application to be most effective should be made at about the time the first nymphs to hatch are near the last molt. This is indicated by the length of the wing pads.

(See fig. 3.) At this time the underside of badly infested leaves will be covered by the nymphs in all stages of development. Generally speaking, this condition is likely to occur in the Lake Erie Valley from July 1 to 15. All of the field experiments conducted in 1910 and 1911 were made between these dates and in every instance very satisfactory results were secured. Since the nymphs continue to hatch over a long period, if the spray application is made while the first nymphs to hatch are quite small large numbers are likely to hatch after the spray application has been made, thus necessitating a second application a few weeks later. On the other hand, if the application is withheld until many of the nymphs have developed wings it is doubtful if large vineyard areas can be treated before a large percentage of the nymphs have reached the winged stage. For it must be understood that the tobacco extracts at the dilutions recommended are effective only against the wingless nymphs infesting the underside of the grape foliage. Where it is necessary to treat large areas for this pest, observation would indicate that spray applications should commence during the first week in July.

Observations on the abundance and the extent of injury wrought by this insect pest of the grapevine in the vineyard areas of New York, Pennsylvania, and Ohio bordering on Lake Erie, and also in the vineyard areas of Michigan, indicate that its depredations have increased during the past few years. Progressive vineyardists are commencing to realize that the accumulated injury to the vines by this pest is responsible for curtailment in crop yield and inferiority in quality of fruit wherever it is present on grapevines in large numbers and that steps must be taken to accomplish its control. It is for this reason that the experiments presented in this paper were undertaken, and it is hoped that the results obtained are of sufficient commercial value to encourage grape growers having vineyard areas infested by the grape leafhopper to adopt this method of control.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE GRAPE-BERRY MOTH.

(*Polychrosis viteana* Clem.)

By Fred Johnson and A. G. Hammar,
Entomological Assistants.

INTRODUCTION.

The grape-berry moth, *Polychrosis viteana* Clem. (Pl. IV), is an insect enemy of the grape of long standing in the vineyards of the Lake Erie Valley. Since the first reports of its serious injury to the grape crop near Hudson, Ohio, in 1868, it has been an almost continual menace to grape production in vineyards located along the shores of Lake Erie from Sandusky in Ohio eastward into Pennsylvania and New York. Most of the data dealing with this insect cover a series of life-history records and field experiments conducted during the seasons from 1907 to 1909, inclusive, in connection with the investigations of the grape rootworm and other insect pests of the grapevine which have been carried on at North East, Pa., by the section of the Bureau of Entomology engaged in decidciduous fruit insect investigations under the direction of Mr. A. L. Quaintance.

Before entering into a discussion of the detailed life-history studies and remedial measures, a brief résumé of an historical nature is given, showing the attention this insect has received from earlier entomologists. In treating of its origin and distribution it is pointed out that for many years it was confused with the European grape-berry moth, *Eudemis botrana* Schiff., an insect which is very destructive to the berries of grapes in the vineyards of southern Europe and to which it is closely related and bears a very close resemblance, both in appearance and in the manner in which it attacks the grape.

Earlier entomologists credited the grape-berry moth with having a number of food plants, but the studies of the late Prof. M. V. Slingerland in 1903 and 1904 indicate that several other species of Polychrosis have been confused with *P. viteana*, and that the latter feeds and reproduces only in the berries of grapes, wild and cultivated. His conclusions are borne out by the observations made during this investigation, for in no case has this insect been reared from anything but blossom clusters and berries of the grape.

Those regions where serious outbreaks of this pest have occurred have been recorded and the habits of the insect and the character of injury are described in detail. Since the character of injury to the grape berry by the grape curculio (*Craponius inæqualis* Say) coincides quite closely with that of the grape-berry moth, the work of this insect is described in order that the injury done by these two insects may not be confused.

A description is given of the stages of the insect, those of the larval and adult forms being quoted from the paper on "Some new species of Polychrosis," by Mr. W. D. Kearfott.[1]

In connection with the rearing experiments it has been found that a large number of hymenopterous parasites prey upon this insect in its larval and pupal stages, and during this investigation 12 additional parasites have been added to the list recorded by Prof. Slingerland in 1904.

During the seasons of 1907 and 1908 the investigation of the grape root-worm occupied the greater part of the time of the force engaged in the study of grape pests. For this reason the life-history studies covering those seasons were rather fragmentary. During the season of 1909, however, the junior author devoted the greater share of his time to a detailed study of the life history of this pest. From the records secured by him in this relation the data covering the various stages of a large number of individuals, presented under the topic of seasonal history for 1909, have been compiled.

These life-history studies indicate that there is only one full brood of larvæ and a partial second brood each season in this region, whereas it was previously supposed that there were two full broods and a partial third brood of larvæ. These records also show the relation of the emergence of the spring brood of moths to the time of blooming of the grape, and the approximate percentage of first-brood larvæ which appear before and after the blooming period, thus indicating the possible relative value of poison-spray applications made against the larvæ before and after the blossoming period.

Field experiments with poison sprays covering several acres of badly infested vineyard were conducted for the three consecutive seasons of 1907, 1908, and 1909, in the vineyard of Mr. W. S. Wheeler, at North East, Pa. These experiments indicate that on account of the extreme variability of infestation of vineyard areas by this pest it is very difficult to lay out an arrangement of plats which will show the relative value of poison-spray applications of varying strength and time of application. Yet there is no doubt that poison-spray applications, made with thoroughness and with due regard to the manner of application, at the time that the larvæ of the first brood

[1] Trans. Amer. Ent. Soc., vol. 30, pp. 292-293, 1904.

THE GRAPE-BERRY MOTH (POLYCHROSIS VITEANA).

FIGS. 1, 2.—ADULT OR MOTH. FIG. 3.—FULL-GROWN LARVÆ. FIG. 4.—PUPÆ. ALL GREATLY ENLARGED. (ORIGINAL.)

are hatching in large numbers, will result in a considerable reduction in the injury wrought to the grape berries by this pest.

Recommendations offered for the control of this insect in regard to the time and manner of making spray applications are based upon the data obtained in the study of the life history and habits of the grape-berry moth during this investigation, correlated with the field experiments and observations covering that period. Since these life-history studies have shown considerable deviations from those previously recorded in regard to the time of appearance of certain stages of the insect and in the number of broods each season, it has been necessary to revise our ideas somewhat as to the relative importance of the spray applications formerly recommended; and since suitable opportunities have not presented themselves for a thorough trial of this revised spray schedule, some of the recommendations along this line are offered rather in the form of suggestions than as definitely demonstrated and proved methods.

HISTORY.

The American species, *Polychrosis viteana*, was first described by Clemens in 1860, in the Proceedings of the Philadelphia Academy of Natural Sciences. In addition to a description of the adult moth Clemens makes some statements as to the habits and food plants of the larva. (See discussion under Food Plants, p. 20.)

In 1869 Packard, in his "Guide to the Study of Insects," has described this insect under the name of *Penthina vitivorana*. In a footnote, however, he states, "It is the *Lobesia botrana* of southern Europe according to Prof. Zeller."

About this date Dr. C. V. Riley sent some specimens of the American-reared species to Mr. P. C. Zeller, of Stettin, Prussia, who identified them as the European species *Lobesia botrana* and Packard's footnote quoted above is doubtless the result of Zeller's identification of the American specimens sent to Europe by Dr. Riley.

From 1870 until 1903 American entomologists accepted the statement of Zeller that the grape-berry moth found in this country was of European origin. In 1903, however, the study of this insect was taken up by Prof. M. V. Slingerland in the vineyards of Chautauqua County, N. Y. Owing chiefly to some variation in the habits of hibernation of the American species from that of the European species—namely, that it makes its overwintering cocoons on fallen leaves, whereas cocoons of the European species are found upon the trellis posts and the trunks of the vines—and since in addition to this the American grape-berry moth is quite common in the fruit of wild grapevines growing at considerable distances from cultivated grapevines, Prof. Slingerland was led to surmise that the American grape-berry moth is a native American species.

In addition to accepting the conclusion of Dr. Riley and Mr. Zeller that the American grape-berry moth is an introduced species, American entomologists previous to Prof. Slingerland's investigations were under the impression that this insect fed and reproduced on several plants other than the grapevine. During his investigation of this insect Prof. Slingerland reared adult moths from many of the plants upon which the grape-berry moth was supposed to feed and in no case was this insect reared from any other plants than from the fruit and blossom clusters of the wild and the cultivated grapevines. Authentic specimens of the European species were secured by him, and these, together with moths reared from other plants and supposed to be the grape-berry moth, were turned over to Mr. W. D. Kearfott for comparison with a large number of American grape-berry moths reared from the fruit of both wild and cultivated grapes.

These comparisons and rearing records made by Mr. Kearfott and Prof. Slingerland have resulted in the former separating the *Polychrosis viteana* of Clemens from the European species and considering it a distinctly native American species feeding and reproducing solely upon the blossom clusters and the fruit of wild and cultivated grapevines. Closely related forms of Polychrosis reared from plants other than the grape have been divided by Kearfott into several new species.

ORIGIN AND DISTRIBUTION.

In regard to the origin of the grape-berry moth, as mentioned under the topic dealing with the history of this insect, American entomologists previous to the investigations of Prof. M. V. Slingerland considered it to have been introduced from Europe. On page 56 of Bulletin No. 223 of the Cornell Agricultural Experiment Station issued during 1904, Slingerland gives several paragraphs under the heading "Comparative notes on the American and European grape-berry moths" which present his views and conclusions on this subject. These are as follows:

Comparative Notes on the American and European Grape-Berry Moths.

In 1860, Clemens (Proc. Acad. Nat. Sci. Phila., p. 369) named some moths *Endopiza? viteana* which he reared from caterpillars feeding on grape-berries, wild raspberry fruits, and leaves of sassafras. About eight years later, the grape-feeder attained the rank of a serious pest in vineyards, and two other names were suggested for it. Rathvon (Prac. Farmer, Nov. and Dec., 1868, p. 170 and 48) called it the grape codling-moth (*Carpocapsa vitisella*) and Packard gave it the name of *Penthina vitivorana* (Guide the Study of Insects, p. 336). In 1870, however, Riley sent specimens to Zeller in Prussia, and he said they were identical with the European grape-berry moth (*Eudemis botrana* Schiff.), thus relegating the American names into the synonymy where they have since remained undisturbed. As soon as we found that the insect infesting New York grape-berries was not following the scheduled life-history of the European pest, doubts at once arose regarding the identity of the American

and European grape-berry moths in spite of Zeller's dictum which had stood unquestioned for over thirty years. Several authentic specimens of the European moths were obtained and have been critically compared by an expert, Mr. W. D. Kearfott, with dozens of the moths reared from American grapes, both wild and cultivated, and also with the type specimens of Clemens's *viteana* and some of Riley's material. Briefly stated, the conclusion is that the American grape-berry moth is Clemens's *viteana* which is distinct and easily separable from the European insect. This conclusion, based on a comparison of the moths alone, is strongly supported by our observations on the difference in the life-history of the two insects, and the fact that the American insect freely infests both our wild and cultivated grapes.

The general coloration of the moth of the European insect * * * is an ashy gray with pale grayish hind wings, while the American moths range a trifle smaller, and are of a general purplish-brown color with smoky-brown hind wings. And the large outer marginal patch near the fringe of the front wings affords a sure and easy distinguishing mark between the two insects. In the European *botrana*, the outer edge of this pale olive-green patch is rounded and not indented below, while in the American *viteana* this dark-brown patch is indented above the anal angle by a spur of the lighter ground color of the wing. This characteristic difference is well shown in Fig. 24. There is considerable variation in the indentation of this patch in *viteana* but it is always present; we have a few specimens where the indentation extends through the patch, thus making it smaller and separating off a narrow strip of it on the edge of the wing, but this usually occurs on one wing only, the other being nearly normally indented. Superficially the two insects are marked much alike, but are easily distinguished by the characteristic differences in general coloration and the outer marginal patch. Both species are somewhat variable in size and markings, as shown in Figs. 20 and 24.

An excellent, detailed, 75-page account by G. Del Guercio of the European grape-berry moth was published in 1889 (Nouve Relazioni R. Stazione di Entomologia Agraria di Firenze, Serie Prima, No. I, p. 117–193). In a careful comparison of specimens of the early stages of our American species with Guercio's descriptions, we found but few minor differences.

The bulletin from which this quotation was made also contains descriptions, on pages 57 to 59, of several new species of Polychrosis, by Mr. W. D. Kearfott, under the title "Descriptive notes of some new species of American moths that have been confused with the grape-berry moth." The verdict of Prof. Slingerland that *viteana* is a native American species is now quite generally accepted and has been followed in the preparation of this paper.

According to existing authentic records of its occurrence in North America its distribution is confined to those eastern and west-central States of the United States and to those eastern provinces of Canada in which the growth of wild and improved varieties of American species of grapes is of considerable extent (see fig. 4). For, so far as is known at the present time, this insect confines its depredations entirely to the fruit of native and improved varieties of American species of grapes. It is not known to occur in the vineyards of the Pacific slope and of adjoining States where the grapevines grown are almost entirely of the European or vinifera type.

The States from which the grape-berry moth has been recorded are given in about the order of destructive occurrence of the insect

as follows: Ohio, New York, Pennsylvania, Indiana, Illinois, Michigan, Missouri, New Jersey, Virginia, Maryland, West Virginia, Iowa, Delaware, and Arkansas. It is also reported as occurring in a number of other States in which the production of grapes is very limited, namely, Massachusetts, Connecticut, Kentucky, Kansas, Texas, Nebraska, and Wisconsin. In Canada it is reported from the vicinity of London, Ontario.[1]

FOOD PLANTS.

When Clemens described the American grape-berry moth in 1860 he recorded it as having several food plants and made the following statements concerning the habits of the larva:

The larva feeds on the fruit of the grape in September; a silken gallery is attached to the external opening of the fruit. Its head is dark brownish; shield blackish; body

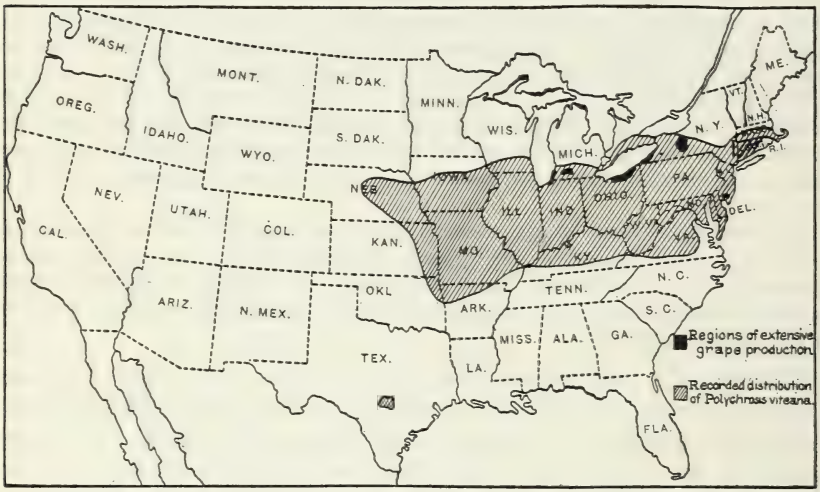

FIG. 4.—Map showing distribution of the grape-berry moth (*Polychrosis viteana*). (Original.)

immaculate dark green. It may likewise be taken on the fruit of wild raspberry. The individual feeding on the grape undergoes transformation by weaving a cocoon on the surface of the ground and that from the raspberry under an excised and turned down portion of leaf. This, however, may not be its normal habit.

Clemens also records it as feeding on leaves of sassafras.

Since that time a number of other entomologists have added several food plants to this list. Packard, in 1868, stated that the first brood feeds on the leaves and tendrils of the grape.

Slingerland gives the following list of food plants added by entomologists during the next thirty years:

Blackberry blossoms (Riley, 1870), roses and *Vernonia* or ironweed (Murtfeldt, 1880 and 1882), tulip-tree leaves and swollen stems of *Amorpha* (Fernald, 1882), flower-buds

[1] SAUNDERS, WM.—Can. Ent., vol. 14, pp. 178–180, 1882.

of common thistle (Coquillett, 1883), berries of wild grapes (Bruner, 1895), grape tendrils and blossoms, seed bunches of sumac, leaves of magnolia, phylloxera lice and their galls (Marlatt, 1896), and moths bred from flower heads of thoroughwort or boneset and *Ambrosia trifida* have been classed with the grape-berry moth in collections.

In all of the rearings of allied moths made by Kearfott and Slingerland, *viteana* was not obtained from any plants other than the grape. This is also true of the rearings made at North East, Pa., during the investigations of grape insect pests which have been conducted there from 1907 to 1911 by the Bureau of Entomology. It is therefore reasonably safe to state that this insect confined its feeding and reproduction to the blossom clusters and berries of the wild and the cultivated grape.

Mr. Kearfott prefaces his paper[1] with the following statement:

> The following notes are from breeding records extending over the past four years, which have convinced me that each of the species described, as well as a number of others waiting for better material, completes its entire yearly cycle of two or three broods on a single food-plant and also with little doubt each food-plant supports a separate and distinct species. This does not seem unreasonable, for in Europe there are twenty described species of the genus *Polychrosis*.

OCCURRENCE OF THE GRAPE-BERRY MOTH IN DESTRUCTIVE NUMBERS.

The earliest record of serious injury by the grape-berry moth in America is from Mr. M. C. Read, of Hudson, Ohio, in 1869. He states that during that season and for several seasons preceding this date this insect had been very injurious to grapes in vineyards in the vicinity of Hudson, Ohio.[2]

Walsh in 1869 states that several persons reported to him observations of its occurrence in injurious numbers in different parts of Missouri and southern Illinois. Riley makes the statement that in 1868 it was common in vineyards in Missouri along the Pacific & Iron Mountain Railroad, and that it was equally common around Alton, Ill. He was also informed that it had ruined 50 per cent of the grapes around Cleveland, Ohio, during the same season.

In 1870 Townend Glover reported it as occurring in large numbers on the fruit of grapevines in Maryland. In 1882 Saunders reported a serious outbreak of the pest in Canada, in vineyards in the vicinity of London, Ontario. In 1885 Dr. F. M. Goding reported it as being very injurious in vineyards near Ancona, Ill. Prof. F. M. Webster reported it as destroying 50 per cent of the grape crop in the vicinity of Cleveland, Ohio, in 1893. In this same year Prof. H. Osborn reported it as being injurious in vineyards near Des Moines, Iowa. In 1898 Prof. Webster again reported it as being very destructive in the vicinity of Cleveland and Gypsum, Ohio. In 1903 and again in 1905 Mr. A. F. Burgess found it very injurious in vineyards in the

[1] Bul. 223, Cornell Univ. Agr. Exp. Sta., pp. 57–59.

[2] Riley, Missouri Report, 1869.

vicinity of Euclid, Ohio. He also reported it as being very injurious in vineyards on Kelleys Island, Ohio, in 1905. In 1906 it was reported by H. A. Gossard and J. S. Houser as again being very injurious in Ohio on Kelleys Island, South and Middle Bass Islands, and also in vineyards along Lake Erie east and west of Cleveland.

Prof. Slingerland (loc. cit.) reported that a correspondent informed him that the crop was entirely ruined by this insect in some vineyards at North East, Pa., in 1896. The same author makes the following statement in regard to serious infestations in the State of New York:

> There are doubtless more or less "wormy" grapes each year in practically every vineyard in New York State, so that the grape-berry moth is a constant menace. But it seems seldom to have been injurious since 1873, when it was first reported as increasing in numbers in the Hudson Valley. In 1898 it was a serious pest in the vineyard of a correspondent at Kendall, N. Y., and in 1902 reports reached us of its ravages all through the Chautauqua grapebelt. From portions of some vineyards near Brocton [N. Y.], a loss of from 25 to 50 per cent was reported, and in one case 90 per cent of the fruit was ruined.

During the investigations of grape insects at North East, Pa., by the Bureau of Entomology, the grape-berry moth was found to be very injurious over limited vineyard areas in this township in 1906, 1907, and 1908. In 1909 and 1910 the injury was not so great. In 1911, however, the infestation was noted to be quite heavy in two or three vineyards. Serious injury was also noted in vineyards in Ohio along the lake shore east and west of Cleveland, and also near Sandusky.

It is evident from these records that this is a serious enemy of the grape, of long standing and wide distribution throughout the vineyard areas of the eastern United States.

In the aggregate the crop loss due to its depredations must be very great, but owing to the irregularity with which the infestation occurs over vineyard areas it is exceedingly difficult to estimate the amount. For this reason the insect has not been subject to the persistent and painstaking efforts for its control on the part of the vineyardist that so destructive an insect pest seems to warrant.

HABITS OF THE ADULT OR MOTH.

The adult grape-berry moth is rarely seen in the vineyard, even in locations where it is quite abundant. It is a small slaty-brown moth with peculiar shaded brown markings on the forewings which render it quite inconspicuous upon the canes of the grapevine. When at rest with the wings folded it is about one-fourth of an inch long (see Pl. IV, fig. 2) and measures less than one-half inch across the outspread wings (see Pl. IV, fig. 1). In captivity in the rearing cages the moths were inactive during the day, remaining stationary upon the canes of the vine beneath the denser foliage or upon the woodwork of the

cage. Their position could be located only after an extended and careful search, so closely did their coloration harmonize with the background upon which they were at rest. Toward evening they became active, flying about the rearing cage and among the foliage of the vine, and at this time of day oviposition on the blossom clusters and berries doubtless occurs. At no time, however, were the females observed in the act of ovipositing. Practically all of the egg deposition on grape berries in the rearing cages occurred at night; hence there is no doubt that the moth is largely nocturnal in its activities. It has been observed quite frequently, however, that in the vineyards egg deposition is much heavier upon the grape clusters that are enveloped in dense foliage. This would indicate that conditions of subdued light are more favorable to oviposition than are exposed positions.

HABITS AND CHARACTER OF INJURY OF THE LARVA.

It is in the larval or caterpillar stage that this insect is injurious to the grape, and, as the popular name of the insect indicates, the berry or fruit is the part of the plant which it attacks. In 1868 Packard recorded the larva as feeding on the leaves, but the next year he corrected this error, and later observations by entomologists have failed to confirm this habit. The first larvæ to hatch are from eggs which are laid by the earliest emerging moths in spring and are doubtless deposited on the unexpanded blossom buds or on the stems of the blossom clusters. These larvæ attack the blossoms and the tiny berries. In the course of its movements, which must cover the entire blossom cluster, the larva spins a silken web. This web binds to each other and to the stem the dried corollas, stamens, and partly devoured berries, forming a conspicuous mass (see fig. 5). Usually, however, these webs formed during the blossoming period of the grape are not very numerous except in those portions of vineyards where the infestation is very heavy. In addition to attacking the blossoms and small berries of the young grape clusters the larva sometimes burrows into the stem, destroying a part of the cluster (see Pl. V, fig. 1). As the berries increase in size the small, scale-like, semitransparent eggs are readily found upon them. The portion of the berry at which the larva enters takes on a conspicuous purple color, and not infrequently the infested berries crack open as illustrated in Plate V, figure 2. In addition to destroying the berry first attacked, the larva connects it to an adjacent berry by silken strands, forming a tunnel between the partly injured berry and the sound one. This forms an avenue of escape for the larva when the berry first attacked is so badly injured that it breaks away from the stem (see Pl. V, fig. 2). When the larvæ of the first brood have

attained full growth they leave the web or the partly grown fruit and travel to the leaves, upon which they form pupal cases. The

FIG. 5.—Injury to grape cluster by larva of grape-berry moth during and just after the blooming period. (Original.)

larva makes the pupal case by cutting away a portion of the leaf and drawing the free edge down to the surface of the leaf with strands

FIG. 6.—Pupal cases made on grape leaf by full-grown larvæ of the first brood of the grape-berry moth. (Original.)

of silk (see fig. 6). The inside of the case is lined with the same silken material. In this case the larva transforms to the pupa (see

FIG. 1.—SHOWING DESTRUCTION OF PORTION OF GRAPE CLUSTER, AS A RESULT OF BORING OF LARVA INTO STEM; NOTE ALSO DRAWING TOGETHER OF BERRIES BY THE WEBB. (ORIGINAL.)

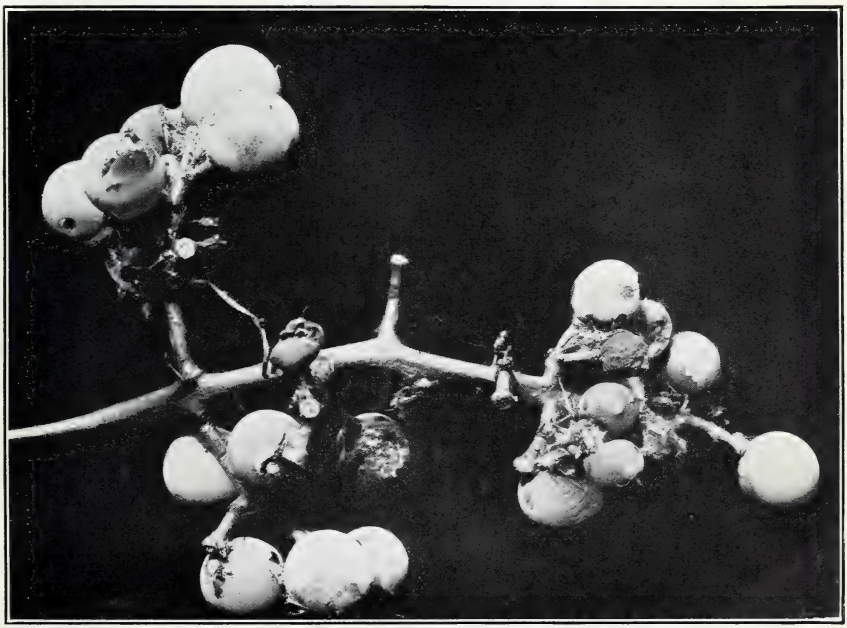

FIG. 2.—SHOWING CRACKING OF INFESTED BERRIES AND ALSO THE WAY IN WHICH BERRIES FIRST ATTACKED ARE SECURED BY WEB TO BERRIES WHICH ARE ATTACKED LATER IN THE DEVELOPMENT OF THE LARVA. (ORIGINAL.)

INJURY TO GRAPES BY LARVÆ OF FIRST BROOD OF GRAPE-BERRY MOTH.

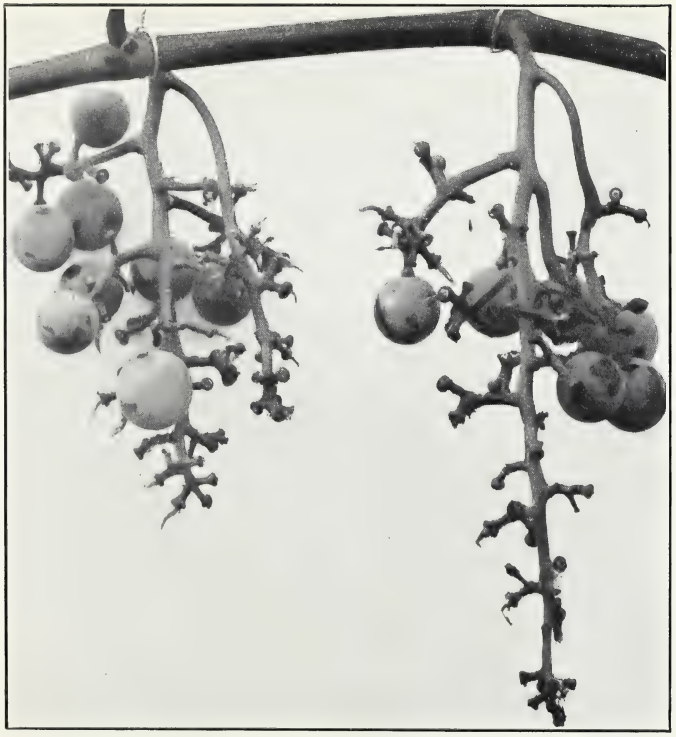

FIG. 1.—SHOWING CLUSTERS OF CONCORD GRAPES FROM WHICH INFESTED BERRIES HAVE BEEN REMOVED. (ORIGINAL.)

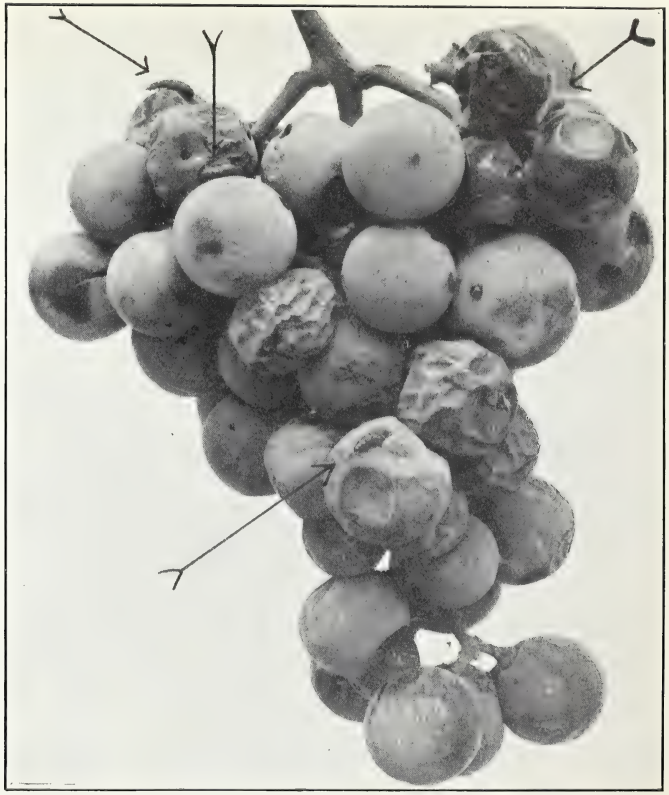

FIG. 2.—INJURY TO BERRIES BY LARVÆ JUST PREVIOUS TO HARVESTING OF FRUIT. (ORIGINAL.)

INJURY TO GRAPES BY LARVÆ OF SECOND BROOD OF GRAPE-BERRY MOTH.

Pl. IV, fig. 4), and the latter emerges as an adult moth (Pl. IV, fig. 1). These moths of the first brood deposit their eggs on the now nearly full-grown berries (see fig. 7). These second-brood eggs are usually more numerous than those of the first brood, if the infestation is at all serious. They are deposited upon the surface of the fruit and are quite conspicuous as white scale-like spots (see fig. 7). When the infestation is very heavy nearly all of the berries

FIG. 7.—Cluster of Concord grapes on which many second-brood eggs of the grape-berry moth are present. The white spots indicate the appearance and position of the eggs. Eggs with black centers were parasitized. (Original.)

in the cluster may be attacked and the fruit rendered worthless. The larva feeds upon the pulp of the fruit and sometimes attacks the seeds before these commence to harden. By the time the grape crop is ready to harvest it is not unusual to find large numbers of clusters injured to the extent shown in Plate VI, figure 1. In Plate VI, figure 2, full-grown larvæ of the second brood are shown in the act of leaving the fruit for hibernation.

DESTRUCTIVENESS OF THE LARVA.

As indicated under the caption dealing with the character of injury, a single larva of the first brood may destroy almost an entire cluster about the time the grapes are in bloom (see fig. 5). For some time after blooming a larva is capable of destroying several berries or even a large portion of the cluster by attacking the stem. When berries are attacked after they have attained the size of a pea, however, rarely more than two or three are destroyed by a single larva. Yet this restriction in the number of berries injured by the individual larva is doubtless more than offset by the great increase in the number of larvæ of the second brood, which are not infrequently

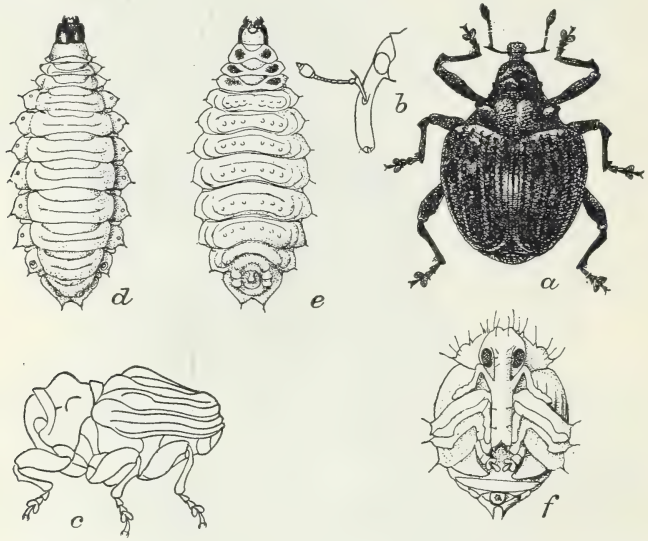

FIG. 8.—The grape curculio (*Craponius inæqualis*): *a*, Adult, or beetle, from above; *b*, head, antenna, and beak of same, from side; *c*, adult, from side; *d*, larva, from above; *e*, same, from below; *f*, pupa, from below. All much enlarged. (From Farmers' Bulletin 284.)

present in sufficient numbers to destroy nearly all of the berries in the cluster, as is shown in Plate VI, figure 1. From these clusters all the infested berries had been removed previous to taking the photograph.

OTHER INSECTS WHOSE INJURY TO GRAPE BERRIES RESEMBLES THAT CAUSED BY THE LARVA OF THE GRAPE-BERRY MOTH.

The only other insect attacking the berries of the grape whose injury to the fruit closely resembles that of the grape-berry moth is the grape curculio, *Craponius inæqualis* Say. This insect, however (see fig. 8, *a*), is one of the snout-beetles or curculios. Its injury to the grape berry is similar to that of the plum curculio upon the plum and other tree fruits. The grape curculio punctures the skin of the

green grape and eats out a small cavity beneath the skin in which to deposit its egg. This injury causes a purple spot on the surface of the berry similar to that which occurs at the point of entrance on the berry by the larva of the grape-berry moth. Where the two insects occur in the same vineyard their work is likely to be confused. The larva hatching from the egg of the grape curculio is a small, white, legless grub which tunnels to the center of the berry, feeds on the pulp, and frequently attacks the seed in much the same manner as does the larva of the grape-berry moth (see fig. 9, *d*). The larva of the grape-berry moth, however, is a caterpillar of a green or purplish color (see Pl. IV, fig. 3), having six well-developed legs and a longer and more slender body, is very active in its movements, and when disturbed by cutting open the berry which it infests is likely to wriggle from its tunnel and drop to the ground.

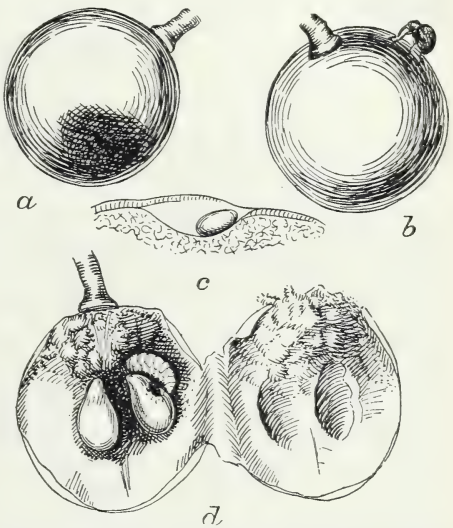

FIG. 9.—Work of the grape curculio in berry of grape: *a*, Berry from which grub or larva has emerged; *b*, adult or weevil ovipositing on berry; *c*, enlarged section of portion of berry, showing egg cavity and egg; *d*, injured berry cut open, showing larva at work. *a*, *b*, *d*, Enlarged; *c*, highly magnified. (From Farmers' Bulletin 284.)

The grape curculio is not a common pest in the vineyards of New York State and in the vicinity of the Great Lakes.

During the investigation of grape insects covering the past five years only two light infestations of this insect have been observed in the vineyards of the Lake Erie Valley. It is, however, a common vineyard pest in West Virginia and in many of the States of the Mississippi Valley and the Middle West. Since the beetles feed on the foliage of the grapevine it is readily controlled by spraying with arsenate of lead, the applications being made at the same date as recommended against the larvæ of the grape-berry moth and the grape rootworm.

An account of the life history and habits of the grape curculio, including methods for its control, are given in Farmers' Bulletin 284 on "Insect and Fungous Enemies of the Grape East of the Rocky Mountains," by Messrs. A. L. Quaintance and C. L. Shear.

There is also a minute chalcis fly,[1] *Evoxysoma vitis* Saunders, which caused some alarm among vineyardists in Canada when it was discovered in the vicinity of London, Ontario, by Saunders in

[1] Can. Farmer, October 15, 1868, p. 316.

1868, infesting seeds of several varieties of cultivated grapes, namely, Clinton, Delaware, Rogers No. 4, and an unnamed seedling variety. Since that time, however, this insect has failed to materialize as a serious enemy to cultivated varieties of grapes. The adult is a minute hymenopterous fly. The female insect deposits its eggs by means of its long ovipositor through the pulp of the grape berry into the seed. The larva hatching from this egg is a minute grub, which feeds upon the pulp within the seed, in which it reaches full development. Grape berries infested by this pest shrivel and drop before the ripening period. This shriveled condition of the berries infested by this grape-seed chalcis is the only evidence of its injury that is likely to be confused with that of the larva of the grape-berry moth.

DESCRIPTION.

THE EGG.

The eggs of the grape-berry moth are oval, scale-like, semitransparent bodies about 1.75 mm. by 1.25 mm. in diameter. They are solidly glued to the surface of the berry and although quite flat they are somewhat more rounded and smaller than those of the codling moth, which they greatly resemble. Before the larvæ hatch from them the eggs are not very conspicuous, especially upon the green berries, since on account of their transparency they become lost in the ground color of the berry. The eggshell is finely reticulate. The development of the larva can be readily observed through the transparent shell. After the larva hatches the eggshell remains upon the surface of the berry and can be more readily seen than the egg itself and appears as a whitish spot possessing a pearly iridescence. Upon the purple background of the ripening fruit the eggs are much more conspicuous than upon the green berries, as shown in figure 7. The eggs with dark centers have been parasitized by the egg parasite *Trichogramma pretiosa* Riley.

THE LARVA.[1]

Larva:—9 to 10 mm. Cylindrical, rather robust, tapering from [segment] 4 to head and [segment] 8 to anal segment. Pale olivaceous-green, with a reddish or purplish tinge from food. Head flattened, slightly bilobed, luteous green on upper parts of lobes, discolored by brown in front; mouth parts and a horizontal dash on side of each lobe below middle black. Pro-thoracic shield large but narrow, luteous brown, bisected by pale green dorsal line. Thoracic feet black, green between joints. Tubercles plates moderate, a slight shade darker than skin, shining. Anal plate not chitinous.

[1] Description by W. D. Kearfott, Trans. Amer. Ent. Soc., vol. 30, p. 293, 1904.

THE PUPA.

The pupæ are 5 mm. (three-sixteenths inch) in length, light greenish brown, with eyes and caudal border of abdominal segments and last two or three segments darker brown. There is a row of coarse short spines near the cephalic border, a row of finer ones along the caudal border of the dorsum of each abdominal segment, and eight bristles, with recurved tips for hooking into the silken cocoon, occur around the tip of the abdomen. On emergence of the adult from the cocoon the exuviæ are drawn about halfway out of the cocoon.

THE ADULT.[1]

Endopiza viteana Clem., Proc. Acad. Nat. Sci. Phila. 359, 1860.
Carpocapsa vitisella, Rathvon, Prac. Farmer, p. 170, 1868.
Penthina vitivorana Pack., Guide Study Ins., 336, 1869.

Head, thorax, palpi light brown, specked with darker brown, lower and outer sides and tips of palpi and posterior thoracic tuft dark brown.

Forewing:—Ground color, lilaceous-blue, middle fascia and large spots brown, overlaid with much black. Costal spots lighter brown. A dash of white about middle of outer third.

Base to middle fascia lilaceous-blue, inner fascia almost obsolete, represented by a narrow band of black scales, each fringed with light brown, from dorsum but not reaching costa by a quarter, three small spots and two small ones between them of brown-black scales on costa before middle fascia. And in the same space on dorsum four black dots, the dorsal margin narrowly overlaid with light fuscous, brown and black scales, causing a mottled appearance.

The middle fascia is evenly convex on its inner edge, and is of almost even width throughout, except at about middle of wing, the outer edge curves downward and outward at right angles to the band, and then turns abruptly upward to costa (in the curve thus formed rests the white oblique patch) from outer end of this branch the outer line of fascia continues inwardly oblique to costa, slightly indented, the lower half of fascia triangular. Color smoky-black on upper half, a small patch of same at one-third above dorsum, otherwise smoky brown, lightest at dorsum. Before anal angle is a triangular brown spot. Above the angle an irregular rounded blotch of brown and black, indented at its lower outward corner by a spur of the ground color, its outline also broken by a spur of ground color on its outer upper edge. Apical spot flatly triangular. Ground color of costal margin between fascia and apex, whitish blue, four brown costal spots in this space, the inner a mere outwardly oblique line curving into outer lower end of second spot, latter and fourth are triangular-oblique, third spot rectangular. Below these spots and above the white patch are scattered a few brown scales. Cilia bluish grey, darker at apex and light fuscous at anal angle. Underside dark fuscous, whitish below fold, three geminated whitish spots on costa before apex, and a number of others on extreme edge of costa only, between these and base, cilia darker with narrow light subciliate line.

Abdomen smoky black, with metallic reflection, anal tuft silvery-white above, yellowish beneath, tipped with dark fuscous; underside abdomen whitish; legs same inwardly and between joints, outwardly smoky-black.

Hind wing:—Smoky fuscous, lighter towards base, darkest at apex, cilia paler; underside fuscous.

[1] Description by W. D. Kearfott, Trans. Amer. Ent. Soc., vol. 30, pp. 292–293, 1904.

SEASONAL HISTORY.

Observations on the life history of the grape-berry moth extend over the seasons of 1907, 1908, and 1909. During the latter year special efforts were made to obtain complete records on the development of the insect in its various stages. In many respects the seasonal conditions during 1907 and 1908 were unusual, the spring of 1907 being late and the entire season of 1908 unusually early. The season of 1909 was in most respects normal.

LIFE-HISTORY STUDIES IN 1909.

The emergence record of the spring brood of the grape-berry moth was secured from leaves upon which larvæ had made cocoons during the fall of 1908. These leaves were left out of doors in a cage all

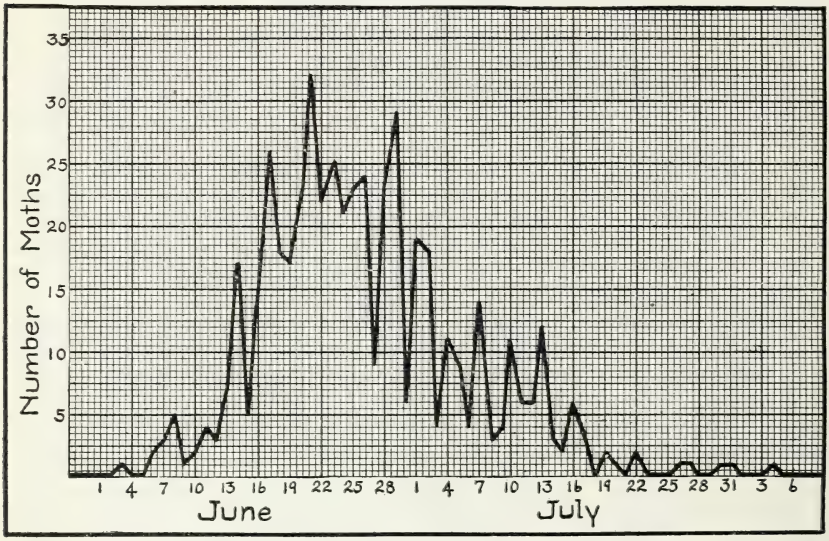

FIG. 10.—Diagram showing time of emergence of spring-brood moths of the grape-berry moth in 1909, at North East, Pa. (Original.)

winter so as to be subject, as nearly as possible, to natural conditions. On May 17, 1909, 1,000 of these cocoons were separated from this mass of leaves and placed in jars in an outdoor rearing shelter (see Pl. VII, fig. 1) and the following emergence record was secured by a daily examination of the jars and the removal of all moths.

SPRING BROOD OF MOTHS.

Time of emergence of spring brood of moths.—Table I gives the emergence of all the moths from these jars. The total number of moths to emerge was 507. The number of moths that emerged from June 3 to June 14 was 28, or 5.5 per cent; from June 14 to July 14, 455, or 89.8 per cent; from July 14 to August 5, 24, or 4.7 per cent. The maximum emergence occurred June 21. (See fig. 10, showing time of emergence of the spring-brood moths.)

TABLE I.—*Time of emergence of moths of the grape-berry moth in the spring of 1909 at North East, Pa.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 3	1	June 18	18	July 1	19	July 14	3	July 30	1
6	2	19	17	2	18	15	2	31	1
7	3	20	23	3	4	16	6	Aug. 1	0
8	5	21	32	4	11	17	3	2	0
9	1	22	22	5	9	19	2	3	0
10	2	23	25	6	4	20	1	4	1
11	4	24	21	7	14	22	2	5	0
12	3	25	23	8	3	23	0		
13	7	26	24	9	4	24	0	Total	507
14	17	27	9	10	11	25	0		
15	5	28	23	11	6	26	1		
16	14	29	29	12	6	27	1		
17	26	30	6	13	12	28	0		

Since the blossoming period of the grape in the Lake Erie Valley occurs usually from June 13 to June 20, this emergence record of the spring moths indicates that the maximum emergence takes place during and after the blossoming period. This record also indicates that the small percentage of webs containing larvæ found in the blossom clusters does not represent the full spring brood from spring-emerging moths, as has been supposed by some investigators, but merely represents the offspring of a very small percentage of the earliest appearing moths.

Oviposition of spring-emerging moths in confinement.—The female grape-berry moth does not oviposit readily in confinement, which accounts for the somewhat meager oviposition records obtained. No eggs were observed in our rearing cages until the berries of the grape were formed and those found were always deposited upon the berries.

TABLE II.—*Oviposition of spring moths of the grape-berry moth in stock jars at North, East, Pa., 1909.*

No. of stock jar.	Number of moths.	Date of—			Days—		
		Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	10	June 17	July 1	July 5	14	5	18
2	30	June 18	June 24	July 2	6	9	14
3	15	June 19	...do....	June 30	5	7	11
4	20	June 20	June 30	...do....	10	1	10
5	46	June 21 to June 22	June 25	July 5	4	11	14
6	12	June 23	June 27	July 7	4	11	14
7	16	June 24	July 1	July 1	7	1	7
8	20	June 25	June 29	July 8	4	10	13
9	23	June 26	June 30	July 12	4	13	16
10	29	June 29	July 7	July 9	8	3	10
Average					6.6	7.1	12.7
Maximum					14	13	18
Minimum					4	1	7

Table II gives a record of oviposition by spring-emerging moths secured during the season of 1909. This table gives the number of days between emergence of the moth and the first oviposition and also the number of days between emergence and the last oviposition. The minimum period before first oviposition was 4 days; the average 6.6 days; the maximum 13 days. The average period between the first and last ovipositions was 7.1 days. The longest period between emergence and the last oviposition was 18 days.

Length of life of spring brood of moths.—Records from our rearing cages show that many of the moths will live in confinement for a number of days, especially when food in the form of honey or sweetened water is supplied. Table III gives the length of life of 76 moths, showing that the minimum life period was 4 days, the average 12.9 days, and the maximum 23 days. The average length of life of the moths recorded in this experiment very closely approximates that of the moths recorded in Table II, which was 12.7 days.

TABLE III.—*Length of life of moths of the spring brood of the grape-berry moth in confinement, with food, at North East, Pa., in 1909.*

Number of moths.	Date—		Length of life.	Number of moths.	Date—		Length of life.
	Emerged.	Dead.			Emerged.	Dead.	
			Days.				*Days.*
4	June 19	July 3	14	3	June 23	July 16	23
4	...do....	July 6	17	10	June 24	July 2	8
4	...do....	July 7	18	1	...do....	July 7	13
2	...do....	July 8	19	1	...do....	July 9	15
1	...do....	July 9	20	1	...do....	July 11	17
6	June 20	June 29	9	4	July 4	July 12	8
5	...do....	July 1	11	2	...do....	July 14	10
8	...do....	July 3	13	1	...do....	July 15	11
2	...do....	July 9	19	1	...do....	July 16	12
6	June 23	July 8	15	3	July 13	July 17	4
1	...do....	July 10	17	2	...do....	July 24	11
2	...do....	July 12	19	2	...do....	July 26	13

Total number of moths 76
Length of life:
Average ..... days.. 12.9
Maximum ..... do.... 23
Minimum ..... do.... 4

FIRST GENERATION.

Incubation period of first-brood eggs.—Table IV gives a record of the length of the egg stage for 21 eggs of the first brood deposited on grape berries in the field rearing cage. The minimum length of the egg stage for this number of eggs was 4 days, the average 6 days, and the maximum 8 days.

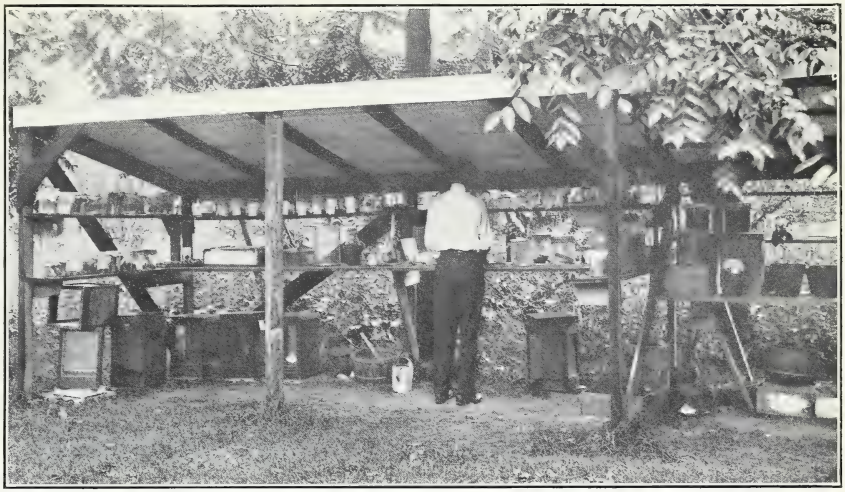

FIG. 1.—PORTION OF OUTDOOR SHELTER USED IN THE REARING OF INSECTS DURING 1909. (ORIGINAL.)

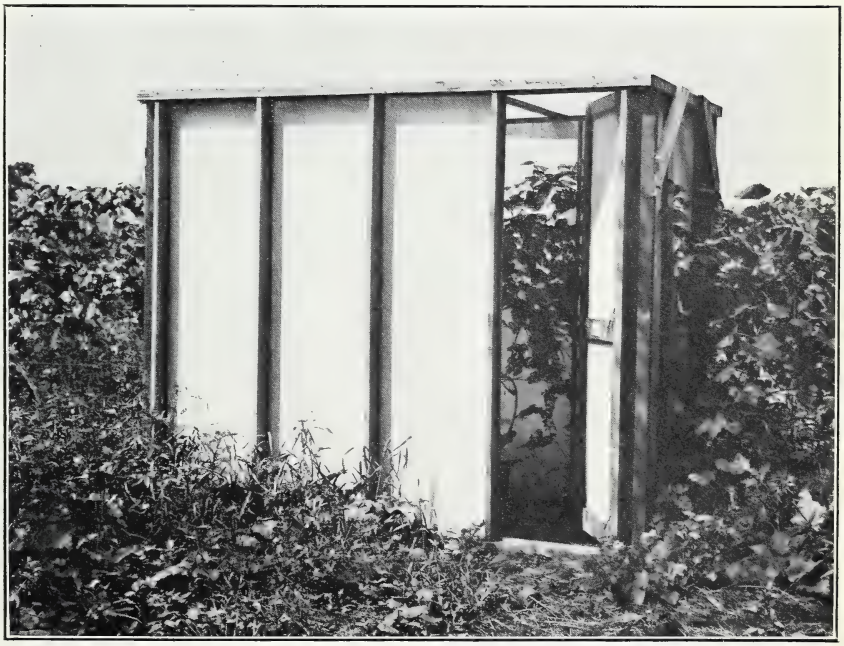

FIG. 2.—CAGE BUILT OVER GRAPEVINE IN WHICH THE GENERATIONS OF THE GRAPE-BERRY MOTH WERE REARED DURING 1909. (ORIGINAL.)

OUTDOOR REARING SHELTER AND CAGE USED IN LIFE-HISTORY STUDIES AT NORTH EAST, PA.

TABLE IV.—*Length of incubation of first brood of eggs of the grape-berry moth at North East, Pa., in 1909.*

No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.
	Laid.	Hatched.			Laid.	Hatched.	
1	June 25	June 29	4	12	July 3	July 10	7
2	June 26	July 1	5	13	...do...	July 11	8
3	June 27	July 2	5	14	July 5	...do...	6
4	June 28	July 4	6	15	July 6	July 12	6
5	...do...	July 5	7	16	July 7	...do...	5
6	June 29	...do...	6	17	July 8	July 13	5
7	...do...	July 6	7	18	July 9	...do...	4
8	June 30	July 7	7	19	July 10	July 16	6
9	July 1	July 8	7	20	July 12	July 17	5
10	July 2	July 9	7	21	...do...	July 18	6
11	...do...	July 10	8				

Days of incubation:

Average	6
Maximum	8
Minimum	4

Length of feeding period of first-brood larvæ.—The records for the length of the feeding period of the first-brood larvæ are given in Table XI (p. 37), which shows a range from 19 to 33 days and an average of 23.2 days. The small number of observations made was due to the difficulty of securing the deposition of a larger number of eggs from the moths in captivity.

Length of pupal stage of first brood.—Table V gives the time of leaving the fruit of 285 first-brood larvæ and the date of emergence of the moths. The average time for making the cocoon was approximately 2 days. The minimum time covered from leaving of fruit to emergence of moths was 10 days, the average 15.2 days, and the maximum 25 days. Therefore, deducting 2 days spent by the larva in making the cocoon the minimum pupal period was 8 days, the average 13.2 days, and the maximum 23 days.

TABLE V.—*Time of cocooning and the length of the pupal stage of the first brood of the grape-berry moth at North East Pa., in 1909.*

Number of larvæ.	Larvæ left fruit.	Moths emerged.	Days—		Number of larvæ.	Larvæ left fruit.	Moths emerged.	Days—	
			In cocoon.	Total.				In cocoon.	Total.
3	July 29	Aug. 10	12	36	3	Aug. 6	Aug. 24	18	54
7	...do....	Aug. 14	16	112	2	Aug. 7	Aug. 20	13	26
2	...do....	Aug. 13	15	30	1	...do....	Aug. 21	14	14
1	...do....	Aug. 23	25	25	7	...do....	Aug. 22	15	105
1	July 30	Aug. 9	10	10	1	...do....	Aug. 23	16	16
2	...do....	Aug. 10	11	22	6	...do....	Aug. 24	17	102
1	...do....	Aug. 12	13	13	1	...do....	Aug. 27	20	20
4	...do....	Aug. 13	14	56	1	Aug. 8	Aug. 23	15	15
9	...do....	Aug. 14	15	135	6	...do....	Aug. 24	16	96
2	...do....	Aug. 15	16	32	17	...do....	Aug. 25	17	289
1	...do....	Aug. 16	17	17	2	...do....	Aug. 26	18	36
8	July 31	Aug. 14	14	112	1	...do....	Aug. 27	19	19
4	...do....	Aug. 15	15	60	1	Aug. 9	Aug. 22	13	13
1	...do....	Aug. 16	16	16	5	...do....	Aug. 25	16	80
14	Aug. 1	Aug. 15	14	196	12	...do....	Aug. 26	17	204
9	...do....	Aug. 16	15	135	2	...do....	Aug. 27	18	36
3	Aug. 2	Aug. 15	13	39	1	Aug. 10	Aug. 22	12	12
8	...do....	Aug. 16	14	112	10	...do....	Aug. 26	16	160
2	...do....	Aug. 17	15	30	9	...do....	Aug. 27	17	153
1	Aug. 3	Aug. 13	10	10	8	...do....	Aug. 28	18	144
2	...do....	Aug. 16	13	26	1	...do....	Aug. 29	19	19
13	...do....	Aug. 17	14	182	1	Aug. 11	Aug. 22	11	11
5	...do....	Aug. 18	15	75	1	...do....	Aug. 25	14	14
3	...do....	Aug. 19	16	48	2	...do....	Aug. 26	15	30
2	Aug. 4	Aug. 17	13	26	4	...do....	Aug. 27	16	64
3	...do....	Aug. 18	14	42	1	...do....	Aug. 28	17	17
2	...do....	Aug. 19	15	30	1	...do....	Aug. 29	18	18
2	...do....	Aug. 20	16	32	2	Aug. 12	Aug. 27	15	30
4	Aug. 5	Aug. 19	14	56	3	...do....	Aug. 28	16	48
5	...do....	Aug. 20	15	75	3	...do....	Aug. 29	17	51
3	...do....	Aug. 22	17	51	1	...do....	Sept. 1	20	20
19	Aug. 6	Aug. 19	13	247					
19	...do....	Aug. 20	14	266	285				4,334
4	...do	Aug. 22	16	64					

	Days.
Average	15.2
Maximum	25
Minimum	10

Time of emergence of first-brood moths.—The material for securing this emergence record of the first-brood moths was taken in part from the large rearing cage in which the eggs had been deposited by earliest emerging moths in the spring. Infested grape berries were removed from the vine in this cage a short time before the larvæ had reached their full growth. The rest of the material was collected from the open vineyard on August 2, 9, and 10. Since larvæ were found in webbed clusters in the open vineyard several days before any larvæ were found in the rearing cage it is probable that a few of the earliest full-grown larvæ of the first brood had escaped from the fruit before it was collected to secure this record, thus making the date of the first-emerging moth in this record a few days later than actually occurred under field conditions. Since the date of the last moth of the spring brood to emerge in our rearing jars was August 4, and the date of the first moth to appear from the first-brood rearing material was July 31, there is evidently an overlapping in the emergence of

moths of the two broods in the field. Table VI contains a record of the emergence of 403 moths, and a glance at the table will show that the maximum number of these first-brood moths emerged from August 14 to August 29. The rate of emergence is graphically shown by the curve in figure 11.

TABLE VI.—*Time of emergence of moths of the first brood (summer moths) of the grape-berry moth at North East, Pa., in 1909.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 31	1	Aug. 19	34	Aug. 30	5	Sept. 10	1
Aug. 9	1	20	32	31	13	11	0
10	5	21	1	Sept. 1	4	12	1
11	0	22	17	2	9	13	3
12	9	23	7	3	7	14	0
13	7	24	19	4	4	15	0
14	18	25	23	5	0		
15	28	26	27	6	4	Total ..	403
16	24	27	23	7	2		
17	18	28	27	8	1		
18	10	29	18	9	1		

Oviposition of first-brood moths.—The oviposition records of only a few moths of the first brood were secured and are not numerous enough to give an adequate idea of the length of this period. The

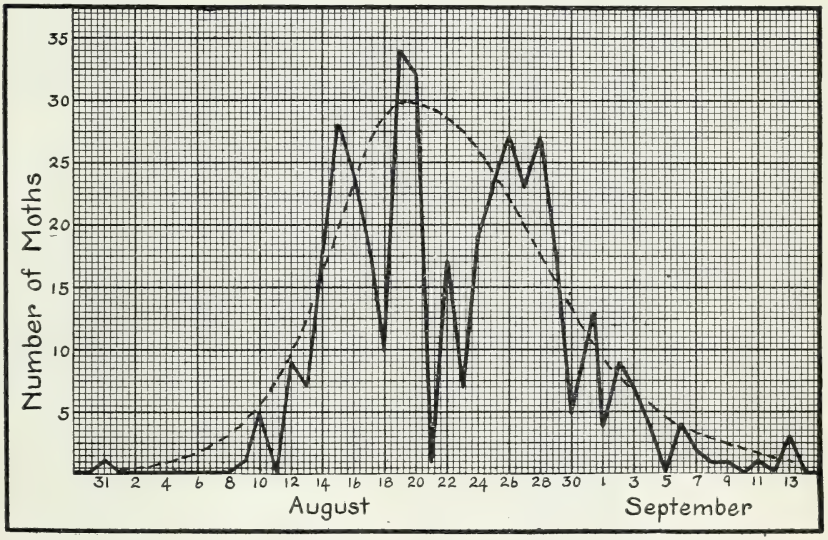

FIG. 11.—Diagram showing time of emergence of the first-brood moths of the grape-berry moth in 1909, at North East, Pa. (Original.)

same difficulty in getting the moths to oviposit freely in confinement was encountered as with the spring-emerging moths. Table VII gives the oviposition of a few individuals of the first brood.

TABLE VII.—*Oviposition of first-brood moths of the grape-berry moth in stock jars at North East, Pa., in 1909.*

No. of stock jar.	Number of moths.	Date of—			Days—		
		Emergence of moths.	First oviposition.	Last oviposition.	Before oviposition.	Of oviposition.	From emergence to last oviposition.
1	10	Aug. 18	Aug. 27	Aug. 27	9	1	9
2	21	Aug. 19	...do....	Sept. 8	8	13	20
3	21	Aug. 20	...do....	Aug. 27	7	1	7
4	4	Aug. 27	Sept. 5	Sept. 5	9	1	1
Average					8.2	4	9.2
Maximum					9	13	20
Minimum					7	1	1

Hibernation of first-brood pupæ.—Toward the end of July before the eggs of the second brood had been deposited a large number of infested grape berries were collected in order to determine if all of the first brood completed the cycle and emerged as adults, or if some of them passed the winter as pupæ.

Tables VIII and IX give the record for 374 larvæ. Deducting the dead and parasitized individuals from this number, a complete record of 321 specimens was secured. Two hundred and ninety-two adults emerged from July 29 to August 15. After the latter date no adults emerged. Twenty-nine live pupæ failed to transform and hibernated.

TABLE VIII.—*The relative number of transforming and wintering individuals of the first brood of the grape-berry moth, North East, Pa., 1909.*

Number of larvæ.	Date larvæ left berry.	Number of—			
		Moths emerged.	Larvæ hibernating.	Larvæ parasitized.	Dead.
19	July 29	13	0	0	6
20	July 30	20	0	0	0
13	July 31	12	0	0	1
21	Aug. 1	21	0	0	0
16	Aug. 2	14	0	0	2
32	Aug. 3	30	0	1	1
13	Aug. 4	10	0	2	1
18	Aug. 5	12	0	2	4
50	Aug. 6	45	0	1	4
23	Aug. 7	19	0	1	3
36	Aug. 8	30	2	0	4
25	Aug. 9	20	0	1	4
32	Aug. 10	24	1	1	6
15	Aug. 11	10	3	1	1
13	Aug. 12	11	1	1	0
1	Aug. 15	1	0	0	0
10	Aug. 26	0	9	0	1
7	Sept. 11	0	7	0	0
5	Sept. 13	0	4	0	1
3	Sept. 12	0	1	0	2
2	Sept. 18	0	1	0	1

TABLE IX.—*Summary of Table VIII showing number and percentage of first-brood larvæ of the grape-berry moth that transform.*

Observations on—	Number.	Per cent.
Number of larvæ	374	100.0
Number of moths emerged	292	78.1
Number of hibernating pupæ	29	7.8
Number of parasitized larvæ	11	2.9
Number of dead individuals	42	11.2

Length of life cycle of first generation.—The results of the preceding observations on the separate stages of the grape-berry moth have been summarized in Table X, which shows an average period of 44.2 days for the life cycle of the first generation.

TABLE X.—*Life cycle of the first generation of the grape-berry moth as determined from observations on the separate stages; summaries from the previous tables.*

Stages of development.	Average.	Maximum.	Minimum.
	Days.	*Days.*	*Days.*
Egg stage	6.0	8	4
Length of feeding	23.0	33	19
Making of cocoon Pupal stage	15.2	25	10
Days duration of life cycle	44.2	66	33

TABLE XI.—*Life cycle of the first generation of the grape-berry moth, as observed by rearing in 1909 at North East, Pa.*

No.	Dates of—					Days duration—				
	Egg deposition.	Hatching.	Leaving fruit.	Pupation.	Emergence of moths.	Incubation of eggs.	Feeding period of larvæ.	Larvæ making cocoon.	Pupal stage	Life cycle.
1	July 2	July 10	Aug. 5	Aug. 9	.....	8	26	4	.....	.....
2	July 3	July 11	July 31	.....	Aug. 14	8	20	.....	.....	42
3	July 5	...do....	...do....	.....	Aug. 18	6	20	.....	.....	44
4	July 7	July 12	...do....	.....	Aug. 16	5	19	.....	.....	40
5	...do....	...do....	Aug. 6	Aug. 7	.....	5	25	1	.....	.....
6	July 8	July 13	Aug. 4	Aug. 6	.....	5	22	2	.....	.....
7	...do....	...do....	Aug. 5	...do....	Aug. 19	5	23	1	13	42
8	...do....	...do....	.....	.....	...do....	5	.....	.....	.....	42
9	July 9	...do....	Aug. 5	Aug. 6	.....	4	23	1	.....	.....
10	...do....	...do....	Aug. 6	Aug. 7	.....	4	24	1	.....	.....
11	...do....	...do....	Aug. 15	Aug. 17	Aug. 31	4	33	2	14	53
12	July 10	July 16	Aug. 5	Aug. 8	.....	6	20	3	.....	.....
Average						5.4	23.2	1.9	13.5	43.8
Maximum						8	33	3	14	53
Minimum						4	19	1	13	40

The average figures in Table X agree closely with the results obtained from the rearings of life-cycle series (Table XI). It will be noted under the life-cycle column that six individuals completed their life cycle the same season, while six pupæ wintered. The shortest

life-cycle period was 40 days, the average length 43.8 days and the longest 53 days. There is a difference of less than half a day in the averages for the two separate rearings.

SECOND GENERATION.

Incubation period of second-brood eggs.—For reasons previously assigned the record of egg laying by the moths in confinement is very scanty. Table XII gives the length of this stage for nine eggs of known origin. The incubation period of these eggs is longer than in the record secured for eggs deposited by the spring-emerging moths. The number of eggs recorded, however, is far too small to admit of generalization on this topic.

TABLE XII.—*Length of incubation of second-brood eggs of the grape-berry moth, North East, Pa., 1909.*

No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.
	Laid.	Hatched.			Laid.	Hatched.	
1	Aug. 27	Sept. 7	11	6	Sept. 2	Sept. 12	10
2	Aug. 30	Sept. 9	10	7	Sept. 4	Sept. 13	9
3	...do.....	Sept. 10	11	8	...do.....	Sept. 14	10
4	Aug. 31	Sept. 11	11	9	Sept. 5	...do.....	9
5	Sept. 1	...do.....	10				

Days of incubation:

Average	10.1
Maximum	11
Minimum	9

Length of feeding period of second-brood larvæ.—Tables XIII–XIV give the feeding period of second-brood larvæ under two entirely different conditions, namely, larvæ reared on green fruit in stock jars under a rearing shelter (Table XIII) and larvæ feeding on fruit growing on a vine (Table XIV) in a large outdoor rearing cage (see Pl. VII, fig. 2).

TABLE XIII.—*Length of the feeding period of the second-brood larvæ of the grape-berry moth under confinement in jars, North East, Pa., 1909.*

No. of observation.	Larvæ hatched.	Larvæ left fruit.	Number of days.	No. of observation.	Larvæ hatched.	Larvæ left fruit.	Number of days.
1	Aug. 27	Oct. 6	40	12	Aug. 30	Oct. 26	57
2	...do.....	Oct. 9	43	13	...do.....	Nov. 1	63
3	Aug. 29	Oct. 17	49	14	...do.....	...do.....	63
4	...do.....	...do.....	49	15	Sept. 11	Nov. 3	53
5	...do.....	Oct. 20	52	16	...do.....	Oct. 25	44
6	...do.....	Oct. 21	53	17	...do.....	Nov. 3	53
7	...do.....	...do.....	53	18	...do.....	...do.....	53
8	Aug. 30	Oct. 22	53	19	...do.....	...do.....	53
9	...do.....	Oct. 25	56	Average			52.6
10	...do.....	...do.....	56	Maximum			63
11	...do.....	...do.....	56	Minimum			40

TABLE XIV.—*Length of the feeding period of second-brood larvæ of the grape-berry moth in fruit on the vines under large outdoor rearing cages, North East, Pa., 1909.*

Number of larvæ.	Larvæ hatched.	Larvæ left fruit.	Number of days.	Number of larvæ.	Larvæ hatched.	Larvæ left fruit.	Number of days.
6	Aug. 25	Sept. 25	31	9	Aug. 25	Oct. 7	43
1	...do.....	Sept. 26	32	1	...do.....	Oct. 8	44
3	...do.....	Sept. 27	33	6	...do.....	Oct. 9	45
9	...do.....	Sept. 28	34	7	...do.....	Oct. 10	46
1	...do.....	Sept. 29	35	7	...do.....	Oct. 11	47
8	...do.....	Oct. 2	38	1	...do.....	Oct. 17	53
7	...do.....	Oct. 3	39	Average			40.3
7	...do.....	Oct. 4	40	Maximum			53
10	...do.....	Oct. 5	41	Minimum			31
8	...do.....	Oct. 6	42				

The infested grape clusters were removed from the cage just before the larvæ were ready to leave the berries. These larvæ hatched from eggs deposited between August 20 and 25. It was impossible to determine the exact date of hatching of all of the eggs, but only a very small number hatched previous to August 25 and this may account in a measure for the shorter average period of feeding than is recorded for the larvæ from the stock jars. In addition to this all but one of these larvæ had left the fruit previous to the occurrence of a decided drop in temperature between October 12 and 20, whereas only two of the larvæ had emerged from the fruit in the stock jars. Hence, since insect activities were slight during this cold wave the period spent in the fruit by those larvæ which had not escaped previous to its occurrence was abnormally prolonged.

The minimum period spent in fruit by larvæ in the rearing cage was 31 days as against 40 days by those in stock jars; the average 40.3 days as against 52.6 days, and the maximum 53 days as against 63 days.

Date second-brood larvæ leave fruit.—A record was made of the period during which the larvæ leave the berries, with a view to ascertaining whether many of them are likely to be removed from the vineyard when the ripe grapes are being marketed. A large number of larvæ which infested grape clusters were collected from vineyards August 20–24. At this date few if any of the larvæ of the second brood had fully matured. Since the emergence of the two broods of moths overlap it is quite likely that some of the larvæ in this record belong to the first brood. Daily examinations of the collected material were made and the record of the larvæ leaving the fruit is given in Table XV.

TABLE XV.—*Time of second-brood larvæ of the grape-berry moth leaving berries in 1909; from fruit collected in the field, North East, Pa.*

Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.	Date of leaving the fruit.	Number of larvæ.
Sept. 22	11	Oct. 6	53	Oct. 20	2	Nov. 3	6
23	21	7	50	21	9	4	0
24	15	8	40	22	5	5	1
25	19	9	38	23	5	6	0
26	8	10	50	24	0	7	1
27	11	11	24	25	7	8	7
28	16	12	14	26	13	9	3
29	21	13	5	27	1	10	0
30	12	14	0	28	0	11	2
Oct. 1	12	15	2	29	4	12	4
2	73	16	1	30	1	13	1
3	39	17	2	31	4	14	2
4	38	18	4	Nov. 1	24		
5	45	19	0	2	19	Total.	745

In all, 745 larvæ emerged. The table shows that 569, or four-fifths of the larvæ, left the fruit in 20 days, from September 22 to October 11, and that the remaining 149, or one-fifth, left the fruit between October 12 and November 14, a period of 34 days, making a total period of 45 days during which second-brood larvæ were leaving the fruit. Since the heavy shipment of Concord grapes does not

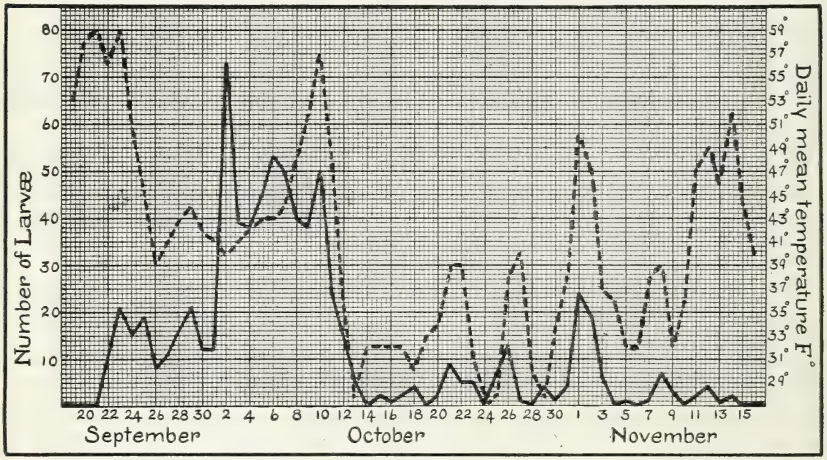

FIG. 12.—Diagram showing time of leaving the grape berries by second-brood larvæ of the grape-berry moth, from fruit collected in the field, North East, Pa., 1909. Daily mean temperature Fahrenheit. (Original.)

occur until October 1, fruit in infested vineyard areas would have to be removed during the first week of the picking season in order to remove many of the larvæ from the vineyard with the crop.

Figure 12 shows the correlation between the fluctuations of temperature and the activity of the mature larvæ of the second brood in leaving the grape berries in the fall of 1909. The dotted line represents the daily mean temperature, and the solid line the rate of emergence of the larvæ from the berries. It will be observed that

there was a period of very low temperature from October 14 to 18, and that this is correlated with an almost complete cessation of emergence of the larvæ. There is no doubt that the abnormally low temperature for this date prolonged the emergence period of the larvæ for the season of 1909.

MISCELLANEOUS REARING RECORDS FOR THE SEASONS OF 1907 AND 1908.

The rearing records for the seasons of 1907 and 1908 are less extensive and not so complete as those made a year later, but they agree in general with the more complete records of 1909. Table XVI gives the emergence record of 24 moths of the spring brood for the season of 1907.

TABLE XVI.—*Time of emergence of moths of the grape-berry moth in the spring of 1907.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 21	1	June 25	4	June 30	1	July 6	1
22	1	26	3	July 2	1	7	1
23	1	28	3	3	1	10	1
24	3	29	1	4	1		

No record of egg deposition by the spring brood of moths was secured for the season of 1907, nor was a record made of the length of the larval stage for the first brood.

The complete record of two pupæ of the first brood was secured during 1907 which covered a period of 13 days for this stage, and a record of one pupa in 1908 which covered a period of 12 days. These records are shorter than the average length of this stage for a large number of specimens observed in 1909 (see Table V, which shows a period of 15.2 days).

An emergence record of 695 moths of the first brood was secured during the season of 1907. (See Table XVII.) Unfortunately some of the earliest maturing larvæ had escaped from the infested fruit before it was collected. Hence some of the earliest emerging moths are not shown, since the first emergence in this record is dated August 17.

TABLE XVII.—*Time of emergence of first-brood moths of the grape-berry moth, North East, Pa., 1907.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
Aug. 17	56	Aug. 26	105	Sept. 1	22	Sept. 9	39
19	5	27	33	2	13	11	19
20	29	28	36	3	7	14	3
21	70	29	60	4	11		
22	34	30	36	5	22	Total	695
24	57	31	28				

Figure 13 gives a graphic representation of the rate of emergence of the moths of the first brood for the season of 1907.

The most extensive record of the egg stage of the second brood was secured in the season of 1907. Table XVIII gives the length of this stage for 35 eggs, which shows an average of 6.5 days, the

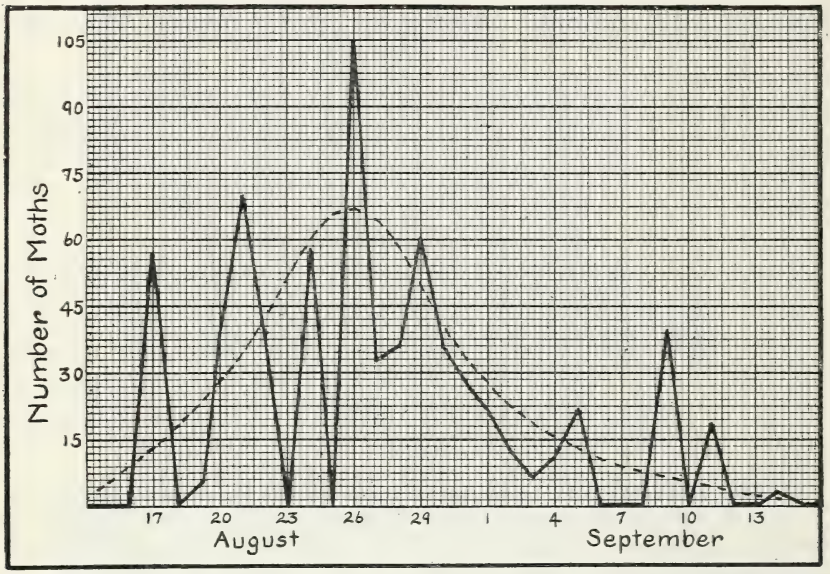

FIG. 13.—Diagram showing the time of emergence of the first-brood moths of the grape-berry moth in 1907, at North East, Pa. (Original.)

minimum being 5 days and the maximum 9 days. This record shows a shorter period than that secured for a smaller number of eggs in 1909 (see Table XII, which shows an average of 10.1 days, a minimum of 9 days, and a maximum of 11 days).

TABLE XVIII.—*Length of incubation of second-brood eggs of the grape-berry moth, North East, Pa., 1907.*

No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.	No. of observation.	Date—		Days of incubation.
	Laid.	Hatched.			Laid.	Hatched.			Laid.	Hatched.	
1	Aug. 31	Sept. 6	6	14	Sept. 1	Sept. 9	8	27	Sept. 10	Sept. 16	6
2	...do....	...do....	6	15	...do....	...do....	8	28	...do....	Sept. 17	7
3	...do....	...do....	6	16	...do....	...do....	8	29	Sept. 11	Sept. 16	5
4	...do....	...do....	6	17	...do....	...do....	8	30	...do....	Sept. 17	6
5	...do....	Sept. 7	7	18	Sept. 10	Sept. 16	6	31	...do....	...do....	6
6	...do....	...do....	7	19	...do....	...do....	6	32	Sept. 12	...do....	5
7	...do....	...do....	7	20	...do....	...do....	6	33	...do....	...do....	5
8	...do....	...do....	7	21	...do....	...do....	6	34	...do....	...do....	5
9	...do....	...do....	7	22	...do....	...do....	6	35	...do....	Sept. 18	6
10	...do....	Sept. 8	8	23	...do....	...do....	6				
11	...do....	...do....	8	24	...do....	...do....	6		Average		6.5
12	...do....	...do....	8	25	...do....	...do....	6		Maximum ...		8
13	Sept. 1	Sept. 9	8	26	...do....	...do....	6		Minimum		5

Table XIX gives the emergence record of 279 moths of the spring brood for the season of 1908. There is a variation of several days in the dates of the maximum emergence of the moths for the three seasons, the maximum emergence being nearly a week earlier in 1908 than in 1907 and 1909. In each instance, however, the period of maximum emergence of the moths coincided quite closely with the period of full bloom of the grape.

TABLE XIX.—*Time of emergence of moths of the grape-berry moth in the spring of 1908, North East, Pa.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
June 1	6	June 19	15	July 3	3	July 15	1
June 7	5	June 20	15	July 5	1	July 16	1
June 8	17	June 21	1	July 6	2	July 17	1
June 9	7	June 22	7	July 8	1	July 19	1
June 10	12	June 23	8	July 9	1	July 20	2
June 12	16	June 24	9	July 10	1	July 22	1
June 13	30	June 25	4	July 11	1	July 23	2
June 15	14	June 26	3	July 12	1	July 25	1
June 16	22	June 29	11	July 13	1		
June 17	17	July 1	1	July 14	4	Total .	279
June 18	33						

Figure 14 gives a graphic description of the rate of emergence of the spring brood of moths for 1908, showing that the maximum number of moths emerged after June 13—about the date that grapes normally commence to blossom.

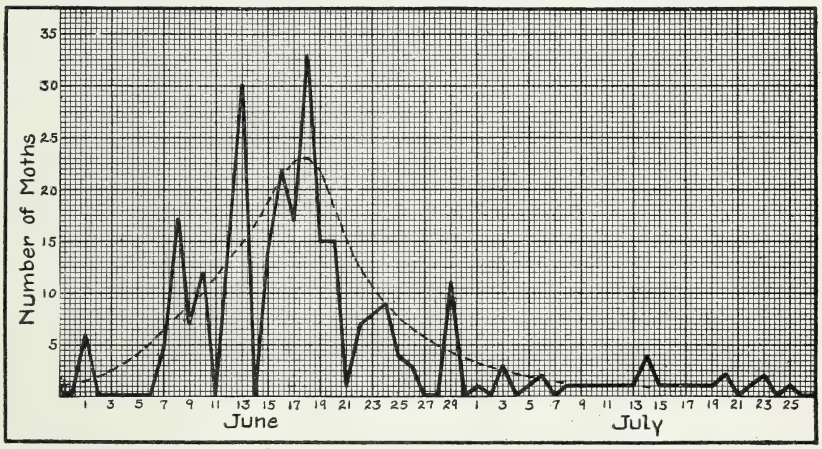

FIG. 14.—Diagram showing the time of emergence of the spring-brood moths of the grape-berry moth in 1908, at North East, Pa. (Original.)

The first record of oviposition in 1908 was made of eggs found in very small berries in rearing cages June 17. No record of the egg stage of the first brood was secured, on account of great difficulty in getting moths to oviposit in confinement. The larval period

of one specimen of the first brood in 1908 was secured. This larva hatched June 20. It emerged from fruit and started to make its pupal case July 10, and had transformed to pupa by July 12, making the larval stage 22 days in length. This period coincides quite closely with the average larval period secured for several larvæ of the first brood during the season of 1909, which was 21.25 days.

The earliest record of emergence of first-brood moths was made on July 13 from a pupa found July 1 on a leaf in the rearing cage in 1908. This is 10 days earlier than the record for other moths from the same source (see Table XX). The emergence record in this table is doubtless somewhat abnormally early, owing to the fact that the temperature in the rearing cage was several degrees higher than outside.

TABLE XX.—*Time of emergence of first-brood moths of the grape-berry moth. North East, Pa., 1908.*

Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.	Date of emergence.	Number of moths.
July 23	3	July 26	26	July 29	4	Aug. 1	1
July 24	4	July 27	31	July 30	2		
July 25	8	July 28	9	July 31	3	Total .	91

SUMMARY OF LIFE-HISTORY STUDIES OF THE GRAPE-BERRY MOTH.

Life-history studies of this pest at North East, Pa., during the seasons of 1907, 1908, and 1909 indicate that there is only one full brood of larvæ and a partial second brood each year in the vineyards of the Lake Erie Valley. The partial second brood of larvæ, however, is larger in numbers than the full first brood, probably on account of the large number of fatalities that occur among the pupæ during the winter season which tends materially to lessen the number of moths that emerge in the spring. The moths from overwintering pupæ commence to emerge about June 1. (See fig. 15, with curve showing length of the various stages of the grape-berry moth for the season of 1909.) Less than 25 per cent of these spring-emerging moths appear before the grape is in full bloom. The total emergence period of the spring moths is about 60 days. As the period of maximum emergence is from June 10 to July 10, it overlaps into the emergence period of the first brood. About 4 to 6 days elapse between the emergence of the moths and the deposition of eggs. The egg stage of the first brood covers about 6 days. The larval period covers about 23 days and the pupal stage about 13 days. A small percentage of the pupæ of this first brood pass the winter. The moths of the first brood commence to emerge during the latter part of July, the maximum number emerging from about August 10 to September 1. The period of incubation of the second-brood eggs is a little longer than

that of the first brood. (See Tables IV and XII.) The larval stage of this brood is also longer than that of the first brood, the average being 22 days for the first brood of larvæ as against 40 days for the larvæ of the second brood. The larvæ of the second brood commence to leave the fruit about the middle of September. The maximum number of larvæ leave the fruit during the last week in September and the first 10 days in October. By October 15 the number of larvæ found in the fruit upon the vines is very small. By this date practically all of them have dropped to the ground and formed pupal cases on the small percentage of grape leaves that have fallen prematurely from the vines. Rarely is a pupal case of this second brood found on the leaves attached to the vines. On

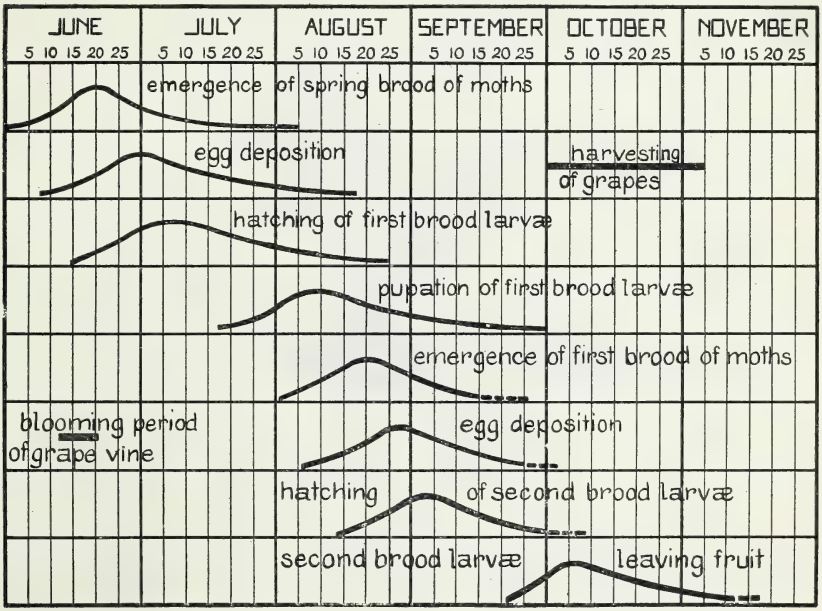

FIG. 15.—Seasonal history of the grape-berry moth as observed in 1909, at North East, Pa. (Original.)

the moist leaves on the ground beneath the vines the second-brood arvæ and also a small percentage of the first brood make their cocoons and pass the winter as pupæ.

PARASITIC ENEMIES.

Detailed studies of the habits and life history of the grape-berry moth during the past few years have shown that this insect is beset with a large number of hymenopterous parasites. Previous to the study of the habits of this pest made by Prof. M. V. Slingerland in the vineyards of Chautauqua County, N. Y., the only record of attack by parasites found in the literature on this subject is made by Dr. C. V. Riley in 1869. Two maggots were found by him destroying

the larvæ of the grape-berry moth, but be failed to rear the adult parasites from them.

During his studies of this insect covering the seasons of 1903 and 1904, Prof. Slingerland reared six different kinds of parasites of the grape-berry moth, which he considered an unusually large number. Four of these were ichneumonids and two were braconids. These rearings by Prof. Slingerland are quoted as follows:[1]

Bracon scrutator Say. (Boston Journ. Nat. Hist., I, 254). The maggot of this little Braconid parasite seems to feed externally on the nearly full-grown caterpillars of the second brood at work in the green fruit in August. Their little, white cocoons are spun in the infested berries. The adults emerged in about two weeks on the following dates: Aug. 28, Sept. 1, 4, and 10.

Bathymetis sp. near *terminalis* Ashm. We reared two females of this comparatively large parasite from hibernated pupæ on May 31. The grape-berry moth caterpillar

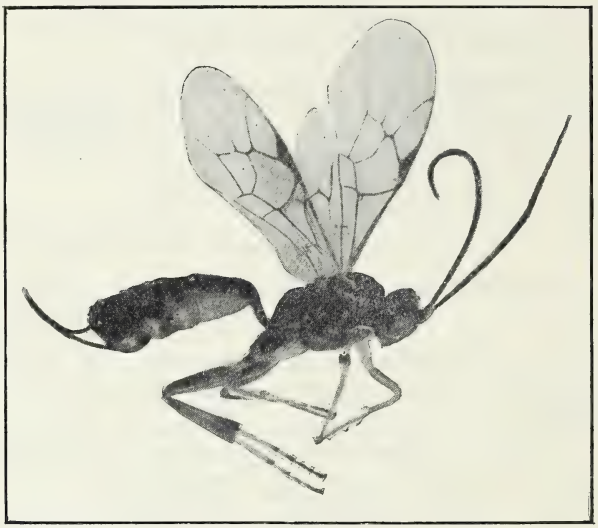

FIG. 16.— *Thymaris slingerlandana*, a common parasite of the grape-berry moth. Enlarged. (After Slingerland.)

had pupated and the parasite's cocoon filled that of its host. Dr. Ashmead reports our specimens as probably undescribed, but possibly *terminalis*, which was described from a male only.

Glypta animosa Cress. (Trans. Am. Ent. Soc., III, 154). One specimen of this Ichneumon emerged from an over-wintered cocoon on June 4. It spun a very thin cocoon and had evidently killed the caterpillar, as no trace of a pupa was found. The recorded hosts of this parasite are *Pædisca scudderiana*, two other Tortricids and a Pyralid.

Glypta vulgaris Cress. (Trans. Am. Ent. Soc., III, 157). Two specimens of this common parasite emerged on August 25 and 27 from thin, white cocoons nearly filling their host's cocoon in a wild grape. Like *Glypta animosa*, this species evidently kills the caterpillar, but it works on the summer brood. It is also parasitic on a species of *Gelechia* and on a Pyralid (*Margaronia quadristigmalis*).

[1] Bul. 223, Cornell Univ. Agr. Exp. Sta., pp. 52–53, 1904.

Urogaster [=*Apanteles*] *canarsiæ* Ashm. (Ent. Soc. Wash., IV, 127, with figure). Found the cocoons of this probable parasite in the webbed blossoms where grape-berry moth caterpillars had worked. Two specimens emerged on July 3 and 7. Its other known host is the Pyralid (*Canarsia hammondi*).

Thymaris slingerlandana Ashm. [fig. 16] (Can. Ent., XXXVI, Nov., p. 333). From August 15 to 27, we reared 17 specimens of this little black Ichneumon with orange-colored, light yellow-banded legs from the cocoons of the grape-berry moths working in both wild and cultivated grapes. Its cocoon occupies about half the space inside the host's cocoon, and evidently the caterpillar was its victim.

In the miscellaneous rearings of the different stages of the grape-berry moth made at the field laboratory of the Bureau of Entomology at North East, Pa., from 1906 to 1911, in connection with life-history studies, together with parasitized specimens observed and collected in the vineyards, 12 additional hymenopterous parasites of different species have been recorded as preying upon this insect. This makes a total list of 17 different parasites known to prey upon this vineyard pest in the Lake Erie Valley at some stage or other of its life cycle. This is a long list of natural enemies for an insect. These parasites are doubtless an important factor in reducing the numbers of the grape-berry moth and their occurrence may explain to some extent the fluctuations in its numbers which occur from year to year.

In the rearing work conducted at North East, Pa., all of the adult parasites emerged from jars containing either larvæ or pupæ of the grape-berry moth during the period between July 12 and September 14. No parasites were collected in the early spring from overwintering cocoons, although a large amount of this material was carried over the winter of 1908 for the purpose of making life-history studies during the season of 1909. This would indicate that parasitism is most active upon the developing first brood of larvæ and pupæ about the period at which this brood exists in the greatest numbers. It would seem, therefore, that the great activity of these parasites during this period must be an important factor in curtailing the second brood of grape-berry moth larvæ that is so destructive to the grape berries at the approach of the ripening season.

Five of the parasites reared were braconids, seven were ichneumonids, all reared from larvæ and pupæ, and one, a chalcidid, reared from the eggs of the grape-berry moth. All of the parasites with the exception of the egg parasites were determined by Mr. H. L. Viereck, of the Bureau of Entomology. Their names are given in Table XXI, which also gives the date of their emergence, the stage of the host, the number reared, and the other host insects from which they have been previously recorded.

TABLE XXI.—*Parasites reared from the grape-berry moth (Polycrosis viteana) feeding upon the fruit of wild and cultivated grapes at North East, Pa., 1906–1911.*

Family.	Date of emergence.	Stage of host.	Number of specimens reared.	Previously recorded hosts.
BRACONIDÆ.				
Microbracon mellitor Say	Aug. 6–19, 1909	Larva	15	Many species of Coleoptera and Lepidoptera.
Microbracon dorsator Say	Aug. 3–Sept. 1, 1911	do	9	Do.
Apanteles sp	Aug. 12, 1911	do	1	No record.
Ascogaster carpocapsæ Vier	Aug. 14, 1911	Pupa	4	Carpocapsa pomonella.
Meteorus sp	Aug. 9, 1909	Larva or pupa.	1	No record.
ICHNEUMONIDÆ.				
Phytodietus sp	July 13, 1906	Larva	1	Do.
Epiurus indagator var. nigrifrons Vier.	Aug. 5, 1911	do	2	Do.
Orthizema sp	July 13, 1908	do	1	Do.
	Sept. 13, 1907	do	2	
Omorgus nolæ Ashm. race	Aug. 16–22, 1909	do	2	Nola sp., a pyralid
Dioctes obliteratus Cress	July 13, 1906	Pupa	1	Gelechia rubidella.
Dioctes obliteratus Cress	July 21, 1907	do	2	Do.
Dioctes obliteratus Cress	July 22, 1908	do	1	
Dioctes obliteratus Cress	Aug. 2–27, 1909	do	27	Do.
Dioctes obliteratus Cress	Aug. 2–27, 1911	do	21	Do.
Ameloctonus sp	Aug. 24, 1909	do	3	No record.
Itoplectis conquisitor Say	Aug. 3, 1911	do	2	Many species of tortricids, noctuids, bombycids, and tineids.

In glancing over this table it will be observed that the parasite reared in greatest numbers from the grape-berry moth was *Dioctes obliteratus* Cress. Mr. Viereck states that the supposedly new species reared by Prof. Slingerland in 1904 and named by Dr. William H. Ashmead [1] as *Thymaris slingerlandana* Ashm. (see fig. 16) is the same as *Dioctes obliteratus* Cress. The largest number of parasite specimens reared by Prof. Slingerland belonged to this species; hence it is very probable that it is quite widely disseminated throughout the vineyards of the Chautauqua County grape belt wherever the grape-berry moth abounds, and is perhaps the most effective enemy of the grape-berry moth of all of the parasites mentioned in this list.

In addition to the parasites previously mentioned as attacking the larvæ and pupæ, on September 7, 1906, a large number of parasitized eggs of the grape-berry moth were found in a badly infested portion of the vineyard of Mr. W. S. Wheeler at North East, Pa. A number of adults were reared from these parasitized eggs and later identified by Dr. Howard as *Trichogramma pretiosa* Riley. This is the first record of parasitized eggs of this insect that has come to our notice, and it is the only instance in which this condition has been observed during this investigation.

[1] Can. Ent., vol. 36, pp. 333–334, November, 1904.

DEGREE OF VINEYARD INFESTATION IN ERIE COUNTY, PA.

The infestation of vineyards by this pest is by no means general. It frequently happens that serious infestation will be confined to one or two rows along the edge of a vineyard or running in for a few vines at the end of a number of rows, or again, in an irregular patch at the corner of a vineyard. Usually such areas of very serious infestation are adjoining hedgerows, fences, or bordering rough lands which admit of the accumulation of leaves and trash. On the other hand, the worst infestation over a large area coming under our observation was in a vineyard which was surrounded by neither hedges nor ditches, was a considerable distance from woodlots or rough land, and was subject to clean culture and excellent care. Again, it is not unusual to find a vineyard portions of which have been badly infested for a number of seasons but adjacent vineyards comparatively free from infestation. Because of this seemingly erratic infestation it is exceedingly difficult either to estimate the actual damage wrought by the pest or to secure reliable results for comparison as to the amount of benefit from remedial treatment. Another result of this erratic infestation is that the vineyardist will minimize the extent of the injury or even entirely overlook it until picking time, when he is astonished to discover the large amount of damage that has been done. When this abundant evidence of injury is brought so clearly to his attention at picking time he is likely to make a vow to take some steps toward the eradication of the pest next season, but only too often, unless the first brood is extremely abundant, the period for effective treatment is again permitted to slip past and the extent of injury at picking time is likely to be the same as in previous years. An additional result of this somewhat restricted and local infestation is that methods of control of the pest are not so freely discussed among the vineyardists and there is not the impetus of a general effort to effect its control that there is in the endeavor to combat an insect whose injury is more apparent and widespread, as in the case of the grape rootworm and the grape leafhopper.

The statements dealing with the destructiveness of this insect in the preceding paragraphs apply to the depredations of the pest in the vineyards of the Lake Erie grape belt, where local conditions have been studied closely for several seasons. In the township of North East, Pa., there is an area stretching east of the town to the New York State line and lying south of the Lake Shore Railroad in which are located the vineyards most heavily infested by the grape-berry moth in this region. In the summer of 1906 one large vineyard was visited in this area in which the infestation was quite general and on limited portions of it the fruit was almost unmarketable.

The infested clusters shown in Plate VI, figures 1–2, were taken from this vineyard. In not all of the vineyards in this area is serious infestation so general. In some of them serious infestation is quite local and in others the injury is almost negligible. Outside of this area infestation in vineyards in Erie County, Pa., is more or less local. Yet the insect is always present in sufficient numbers to become a menace at any time that natural conditions favor its rapid increase, and at the present time the insect is responsible for a greater shrinkage in crop yield than most vineyardists are aware.

REMEDIAL MEASURES.

Several methods for the control of the larvæ of the grape-berry moth have been recommended, namely, the destruction of fallen leaves, plowing the vineyard late in the fall or very early in the spring, bagging the clusters, picking the infested berries, removal of infested berries from the vineyard during the harvesting season, and the use of poison sprays.

THE DESTRUCTION OF FALLEN LEAVES.

Since the larvæ of the second brood on leaving the ripening fruit make their cocoons upon the leaves of the grapevine, the destruction of the fallen leaves has been frequently recommended as a means of control. Until within recent years, however, it was not known that practically all of the overwintering larvæ, on leaving the fruit, instead of forming their cocoons upon the grape leaves attached to the vines, drop to the ground and form their hibernating cocoons on the small percentage of prematurely fallen leaves. Observations on the hibernation habits of this insect in infested vineyards at North East, Pa., in the fall of 1906, showed that practically all of the larvæ had emerged from the fruit by the end of the first week in October and that all of the larvæ and pupæ found at that date were in the cocoons made on leaves upon the ground directly beneath the trellis. In practically all cases the leaves upon which these cocoons were made were in close contact with the soil and in a more or less sodden condition, either from moisture absorbed from the soil or as a result of the fall rains. Many leaves bearing cocoons were plastered to the ground as a result of beating rains and even at this early date were in such a state of semidecay that in attempting to gather the leaves they sometimes fell to pieces in much the same manner that a rainsoaked sheet of newspaper will do under the same conditions.

Although hundreds of cocoons were found on these moist leaves upon the ground only one cocoon was found upon the leaves still attached to the vines, and this was imperfectly formed. Practically all of the fruit on the vines examined during the first week in October had been recently infested and was still hanging upon the vines in close contact with the foliage. These observations confirm those

made by Prof. H. A. Gossard in Ohio during the same season. Searches in badly infested vineyards every season since 1906 have shown a similar condition. This habit of the larvæ may be due to the fact that at this season the leaves upon the vines are somewhat withered and brittle. Hence it would appear to be more difficult for the larvæ to fold the flap of the portion of the leaf cut out for making the cocoon, whereas, when the leaves have fallen to the ground and have absorbed moisture from the soil they are less brittle and the flap can be folded much more readily. Whether this is the true cause of the larvæ seeking the leaves on the ground upon which to form their overwintering cocoons or not the fact that they do so has an important bearing upon the practice of destroying fallen leaves as a means of destroying the overwintering pupæ. Since most of the cocoons are made upon a small number of leaves which are stuck more or less firmly to the ground there is little likelihood that many of them will be blown into piles in the corners of vineyards or into hedgerows as has been supposed. Unless these infested leaves are gathered carefully before the period of soaking rains during the late fall and winter they are likely to fall apart and leave the cocoons containing the pupæ in the vineyard. Perhaps an attempt to gather these infested leaves from the ground beneath the trellis during the middle or latter part of October, before the remainder of the leaves have fallen from the vines, would prove more effective than to try to destroy all of the leaves at a later date. There is no doubt that large numbers of pupæ can be collected in this way over limited areas where the infestation is heavy. Unfortunately, however, the vineyardist is too busily engaged in harvesting his grape crop at this time to adopt this method of control.

PLOWING IN LATE FALL OR EARLY SPRING.

Since it is evident that few of the infested leaves are likely to be removed by the winds from the ground beneath the trellis it is quite possible that large numbers of them could be destroyed by plowing the badly infested portion of the vineyards immediately after the crop of grapes is harvested and before the rest of the leaves have fallen from the vines. Plowing at this time would be more likely to insure the covering of the infested leaves than if all of the leaves had fallen, for then the loose leaves would be likely to drive ahead of the plow and force some of the infested leaves to the surface.

Many vineyardists object to fall plowing of vineyards, and, where it is impracticable, early spring plowing is suggested. Care should be taken to throw the soil well under the trellis so that all of the leaves may be covered. Since only a small percentage of the moths emerge before June 1, plowing up to the trellis during the month of May would doubtless cover many of the pupæ.

BAGGING THE CLUSTERS.

In some parts of New York State the fruit on many acres of Niagara grapevines is protected by inclosing each cluster in a paper bag immediately after blossoming. The bagging of clusters of this variety is done primarily for protection against rot. This method of control, however, involves considerable expense and while very effective can not be employed as a means of protection except on choice table varieties, and hence will not appeal to the large producers of grapes for wine or grape-juice purposes.

HAND PICKING INFESTED BERRIES.

By hand picking the infested berries from the clusters in July and early August the size of the second brood may be greatly reduced. The infested green berries are made conspicuous by the presence of a purple spot at the point of entrance of the larvæ. Sometimes the berry cracks open and again several small berries may be tied together by a silken web (see Pl. V, fig. 2). Before the berries in the cluster are large enough to touch each other the infested berries may be readily discerned, but at a later date it is necessary either to handle each cluster or to examine the fruit from both sides of the trellis. The infested berries collected in this way should be removed from the vineyard and the larvæ destroyed. This may be done by immersing the berries in a kettle of boiling water or burying them beneath several inches of soil.

REMOVAL OF "TRIMMINGS."

During the past few years it has become a common practice to pick and pack the fruit in baskets in the vineyard. In this case the "wormy" berries are removed from the clusters and allowed to fall to the ground and thus the larvæ infesting them remain in the vineyard to infest the crop during the next season. A better method which is practiced by some vineyardists is to have each picker carry an extra basket into which these infested "trimmings" can be placed and be removed from the vineyard and destroyed. If the badly infested portions of vineyards are harvested at the very opening of the picking season many larvæ can be destroyed in this way. At a later date in the harvesting season this removal of the worm-injured berries from the vineyard will not be very effective, for, as previously explained, practically all of the larvæ have then left the fruit.

EXPERIMENTS WITH POISON SPRAYS.

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1907.

In the spring of 1907 an experiment was undertaken in the vineyard of Mr. W. S. Wheeler at North East, Pa. (see fig. 17). In 1906 and for several seasons previous the fruit in sections of the vineyard in which this experiment was conducted had been very badly infested by this insect.

The sections were laid off in seven plats of approximately 1 acre each. There were five rows of vines in each plat. (See plan of plat arrangement, fig. 18; dotted lines in figure indicate divisions of plats.)

The insecticides in all cases were applied with Bordeaux mixture since it is desirable to use this fungicide at the time the applications

FIG. 17.—Vineyard in which poison-spray experiments were conducted against larvæ of the grape-berry moth during the seasons of 1907, 1908, and 1909; vineyard of Mr. W. S. Wheeler, North East, Pa. (Original.)

are made against the larvæ of the grape-berry moth, to control fungous diseases, such as black rot and mildew. In all cases where arsenate of lead was used the Bordeaux formula was 5 pounds of lime and 5 pounds of copper sulphate to 50 gallons of water. Where arsenite of lime was used with the Bordeaux an additional pound of lime was used to counteract any free arsenic which might be present.

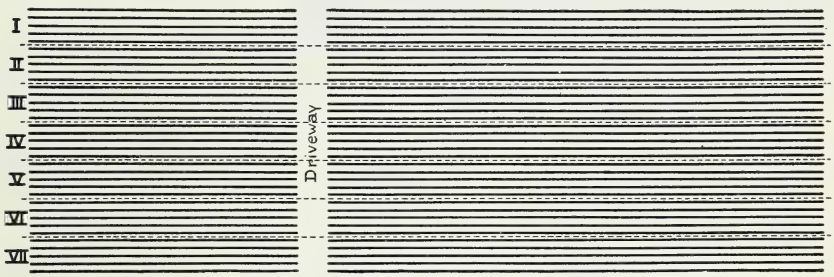

FIG. 18.—Plat arrangement of poison-spraying experiments against the larvæ of the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1907. (Original.)

A gasoline-engine vineyard sprayer outfit (fig. 19) was used for making the application.

The spray was applied to the vines from the machine by means of a fixed-nozzle arrangement (see fig. 19). To a vertical rod on both sides of the back end of the machine two short spurs of $\frac{1}{4}$-inch pipe are attached. Each spur carries a large nozzle of the cyclone type from which the spray is discharged into the side of the vine on the trellis.

A third and upper nozzle is mounted on a longer spur which projects over the trellis. This nozzle is directed downward, throwing the spray upon the topmost growth on the trellis. Such a machine carrying a pressure of 100 pounds and over will force the spray into the vines on the trellis and cover quite thoroughly all of the foliage and fruit clusters, especially during the early part of the season before the foliage has become dense and before the berries in the cluster have become so large that they touch each other.

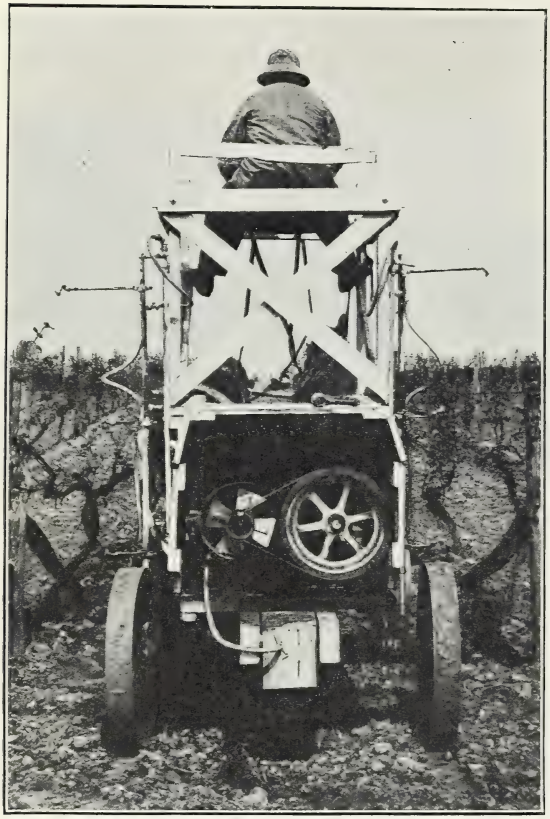

FIG. 19.—Gasoline-engine sprayer outfit used in vineyard experiments against the larvæ of the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1907, 1908, and 1909. (Original.)

In this experiment the team was driven slowly down each row so that the vines were sprayed from both sides of the trellis. A pressure of about 100 pounds was maintained and about 100 gallons of spray were applied per acre.

Table XXII gives the spray treatment applied to each plat and also dates of application.

TABLE XXII.—*Spray formulas and dates of application against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1907.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I.	Three pounds arsenate of lead to 50 gallons of Bordeaux mixture	3	June 19, July 8, 27.
II.	Three pounds arsenate of lead and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	3	Do.
III.	One quart arsenite of lime, Kedzie's formula, and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	3	Do.
IV.	One quart arsenite of lime, Kedzie's formula, to 50 gallons of Bordeaux mixture.	3	Do.
V.	One quart arsenite of lime, Kedzie's formula, and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	2	July 9, 27.
VI.	Unsprayed		
VII.	Three pounds arsenate of lead and 2 pounds resin-fish-oil soap to 50 gallons of Bordeaux mixture.	2	Do.

The variations in the formulas were made to ascertain, if possible, the value of arsenate of lead as against arsenite of lime in the control of this insect. The resin-fish-oil was added on some plats and withheld on others to determine its value as an adhesive in making the spray stick to the grape berries. The variation in number of applications was made to ascertain if applications made before the blossoming of the grape were of greater value than those made after blossoming. The application on June 19 was made when the blossom clusters were well developed, but a few days before actual blossoming (see fig. 20). The application on July 8 was made after blossoming when the berries were about the size of buckshot (Pl. V, fig. 1). At this stage of development the berries stand some distance apart and the spray can be forced through the cluster, so as to cover all of the berries. The application July 27 was made for the purpose of covering the berries to protect them from the entrance of larvæ of the second brood.

FIG. 20.—Stage of development of grape blossom cluster at which poison-spray application should be made against early hatching larvæ of the grape-berry moth which infest the blossom clusters. (Original.)

In all of these applications the work was quite thorough, and with the exception of the third application most of the clusters were well covered by the spray. When the third application was made the foliage had become rather dense, making it more difficult to reach the clusters, and at the same time the berries had increased in size, forming a somewhat compact cluster. These conditions made it increasingly difficult to force the spray in among the berries. Furthermore, too much poison forced into the clusters in this condition is undesirable, since some of it is likely to be present in the cluster when the fruit is ripe and thus render it undesirable for table use.

During the season four counts were made of infested berries on 25 vines in all of the plats. Table XXIII shows the increase in infestation:

TABLE XXIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1907.*

FIRST COUNT OF INFESTED BERRIES MADE JULY 24.

Plat No.	Date of spray application.	Number of applications.	Spray formula.	Number of vines examined.	Total number of clusters.	Average number of berries per cluster.	Number of infested berries.	Total number of berries counted.	Percentage of berries infested.
I.	June 19, July 8, 27.	3	5-5-3-50	25	997	36	205	35,892	0.45
II.	do	3	5-5-3-2-50	25	853	36	83	30,708	.27
III.	do	3	5-6-1 qt.-2-50	25	842	36	113	30,312	.37
IV.	July 9, 27	3	5-6-1 qt.-50	25	835	36	131	30,060	.43
V.	do	2	5-6-1 qt.-2-50	25	744	36	172	26,784	.64
VI.	Unsprayed	None.	None	25	890	36	317	32,040	.98
VII.	July 9, 27	2	5-5-3-2-50	25	1,204	36	126	43,344	.29

SECOND COUNT OF INFESTED BERRIES MADE AUG. 29.

I.	June 19, July 8, 27.	3	5-5-3-50	25	997	36	662	35,892	1.84
II.	do	3	5-5-3-2-50	25	853	36	337	30,708	1.09
III.	do	3	5-6-1.qt.-2-50	25	842	36	432	30,312	1.09
IV.	do	3	5-6-1 qt.-50	25	835	36	330	30,060	1.09
V.	July 9, 27	2	5-6-1 qt.-2-50	25	744	36	419	26,784	1.56
VI.	Unsprayed	None.	None	25	890	36	696	32,040	2.17
VII.	July 9, 27	2	5-5-3-2-50	25	1,204	36	340	43,344	.78

THIRD COUNT OF INFESTED BERRIES MADE OCT. 9.

I.	June 19, July 8, 27.	3	5-5-3-50	25	997	36	2,326	35,892	6.45
II.	do	3	5-5-3-2-50	25	853	36	1,751	30,708	5.70
III.	do	3	5-6-1 qt.-2-50	25	842	36	1,503	30,312	4.95
IV.	do	3	5-6-1 qt.-50	25	835	36	1,083	30,060	3.60
V.	July 9, 27	2	5-6-1 qt.-2-50	25	744	36	1,681	26,784	6.27
VI.	Unsprayed	None.	None	25	890	36	3,549	32,040	11.07
VII.	July 9, 27	2	5-5-3-2-50	25	1,204	36	1,910	43,344	4.40

FOURTH COUNT OF INFESTED BERRIES MADE OCT. 23.

I.	June 19, July 8, 27.	3	5-5-3-50	25	997	36	4,655	27,544	16.90
II.	do	3	5-5-3-2-50	25	853	36	2,295	25,668	9.51
III.	do	3	5-6-1 qt.-2-50	25	842	36	2,648	24,552	10.78
IV.	do	3	5-6-1 qt.-50	25	835	36	2,295	24,232	9.74
V.	July 9, 27	2	5-6-1 qt.-2-50	25	744	36	2,288	23,562	9.71
VI.	Unsprayed	None.	None	25	890	36	3,149	23,000	13.69
VII.	July 9, 27	2	5-5-3-2-50	25	1,204	36	2,338	36,980	6.32

In making these counts it was observed that the infestation was very irregular throughout this block of vineyard. The first two or three rows on Plat I were heavily infested. The fruit on about 20 to 30 vines, on the east end of plats I, II, and III was also quite badly infested. Passing through Plats V, VI, and VII and toward the north side and the west end of the vineyard the infestation was much lighter, and on Plat VII and the extreme west end of Plats IV, V, VI, and VII the infestation was very light. This exceedingly variable condition of infestation has made the tabulation of results very difficult, and it has been quite impossible to bring out the relative value of the different poisons used and the value of the varying number of applications.

The results of the spraying operations for this season are quite indefinite and serve only to bring out the great irregularity in infestation, its progress throughout the season, and the difficulty in laying out a plat arrangement which will show accurately the effect of spray treatment against this pest. That some benefit did result from the spray application is indicated by the fact that in a comparison of infestation in Plats V, VI, and VII, where the infestation was lighter but more uniform than on the opposite side of the vineyard, there was throughout the season a greater infestation on the unsprayed plat than on the two adjacent sprayed plats. There was not sufficient difference in the weight of fruit from the different plats to indicate a commercial value resulting from the use of arsenate of lead as against arsenite of lime.

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1908.

The spray work for 1908 was conducted in the same vineyard as in 1907. The plat arrangement, however, was changed. The number

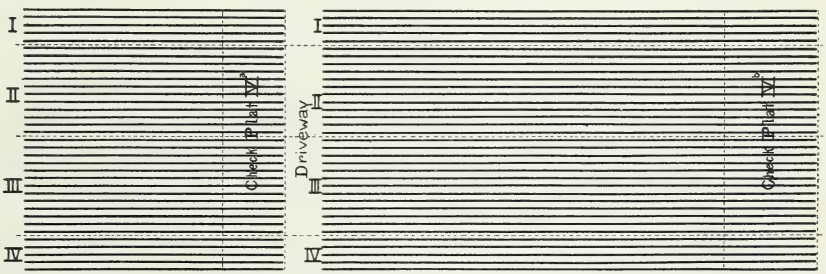

FIG. 21.—Plat arrangement of poison-spraying experiments against the grape-berry moth in the vineyard of Mr. W. S. Wheeler, North East, Pa., 1908 and 1909. (Original.)

of plats was reduced to four. Plat I consisted of 5 rows, Plat II of 12 rows, Plat III of 13 rows, and Plat IV of 5 rows. The position of the check or unsprayed plat was also changed. Checks were left in two places. In the west section 10 vines were left unsprayed on the east end of all the rows of the four plats; in the east section 15 vines were left unsprayed on the east end of all of the rows of the four plats. (See plan of plat arrangement, fig. 21.) The dotted line running across the plats near the east end of both sections indicates the location of the unsprayed check vines; these portions thus separated are numbered Plat V*a* and Plat V*b*, respectively.

This rearrangement of plats was adopted in the hope that the infestation of the vines in these locations would more nearly represent that existing on the sprayed vines.

Arsenite of lime was eliminated from the spray formulas used, on account of slight injury to foliage. The spray formula on all four plats was the same. (See Table XXIV.)

TABLE XXIV.—*Spray formulas and dates of application against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I	Three pounds arsenate of lead and 2 pounds resin-fish-oil to 50 gallons of Bordeaux mixture.	2	June 4, 18.
II	do	3	June 4, 18; July 6.
III	do	2	June 19; July 6.
IV	do	1	June 19.
V *a–b.*	Unsprayed.		

The same spraying machine and the same nozzle arrangement were used as in 1907. The pressure maintained was from 100 to 125 pounds. About 100 gallons of spray were applied per acre. The first application was made June 4, just before the blossom buds opened. A double application was made at this date; that is, as soon as the plats had been sprayed once the same plats were gone over again. Only Plats I and II were sprayed at this date. On June 18, just after blossoming, when the berries were about the size of buckshot (Pl. VIII, fig. 1), all four of the plats were given a double spraying. About 100 gallons of spray were used at each application and a pressure of from 100 to 125 pounds was maintained. Plat II received a third application July 6. This also was a double application. In making these double applications the vines were covered very thoroughly by the spray.

As in the previous season the infestation proved to be widely variable, rendering it impossible to make a comparison of the value of the variation in the number of applications made to the different plats. The infestation was distributed in about the same general manner as in the previous year. Plat I, on the south side of the section, was the most heavily infested, the infestation gradually decreasing in the other plats toward the north side of the vineyard. Counts were made on 25 vines in each of the check plats and also in each of the sprayed plats to show the progress of infestation for the first and second broods. (See Table XXV, showing count of infested berries for 1908.)

TABLE XXV.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

FIRST COUNT OF INFESTED BERRIES, MADE ON AUGUST 3, 4.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I	June 4, 18	5–5–3–2–50	2	25	28
II	June 4, 18; July 6	5–5–3–2–50	3	25	25
III	June 19; July 6	5–5–3–2–50	2	25	21
IV	June 19	5–5–3–2–50	1	25	31

TABLE XXV.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908*—Continued.

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 24 TO 26.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I.	June 4, 18	5-5-3-2-50	2	25	1,855
II.	June 4, 18, 19; July 6	5-5-3-2-50	3	25	1,440
III.	July 6	5-5-3-2-50	2	25	1,095
IV.	June 19	5-5-3-2-50	1	25	960

FIRST COUNT OF INFESTED BERRIES MADE ON AUGUST 3, 4.

V *a–b*	Unsprayed	None	None.	25	387
Do	do	do	None.	25	198
Do	do	do	None.	25	153
Do	do	do	None.	25	67

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 24 TO 26.

V *a–b*	Unsprayed	None	None.	25	4,495
Do	do	do	None.	25	2,899
Do	do	do	None.	25	2,466
Do	do	do	None.	25	1,588

When the fruit was harvested the crop from the sprayed and from the unsprayed plats was weighed. Table XXVI, in the columns under "Yield in pounds of fruit per acre," shows the difference in crop yield per acre on the sprayed and the unsprayed plats. The last column also shows the cash value of the increased yield per acre on the sprayed vines.

TABLE XXVI.—*Amount of fruit infested by the grape-berry moth on sprayed and unsprayed plats and cash value of spray benefit per acre. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1908.*

Plat No.	Date of spray applications.	Number of applications.	Spray formula.	Average number of berries per cluster.	Total number of clusters.	Number of vines examined.
I.	June 4, June 18	2	5-5-3-2-50	36	2,312	60
Va–Vb	Unsprayed			36	3,858	60
II.	June 4, June 18, July 6.	3	5-5-3-2-50	36	3,374	60
Va–Vb	Unsprayed			36	2,294	60
III.	June 19, July 6	2	5-5-3-2-50	36	2,235	60
Va–Vb	Unsprayed			36	1,914	60
IV.	June 19	1	5-5-3-2-50	36	1,751	60
Va–Vb	Unsprayed			36	1,796	60

Plat No.	Total number of berries.	Total number of wormy berries.	Per cent of wormy berries.	Date of examination.	Yield in pounds of fruit per acre.		Cash gain in yield of fruit on sprayed plats per acre (at 1½ cents per pound).
					Sprayed.	Unsprayed.	
I.	83,232	4,452	5.3	Sept. 26	4,175	3,347	$12.42
Va–Vb	102,888	11,989	11.6	...do.....			
II.	85,464	3,458	4.4	...do.....	3,826	2,998	12.42
Va–Vb	82,584	7,733	9.2	...do.....			
III.	80,460	2,632	3.2	...do.....	3,949	3,010	14.08
Va–Vb	68,904	6,577	9.8	...do.....			
IV.	63,136	2,309	3.6	...do.....	3,186	2,455	10.96
Va–Vb	64,656	4,136	6.3	...do.....			

VINEYARD EXPERIMENTS WITH POISON SPRAYS IN 1909.

The spray work for 1909 was conducted in the same vineyard as in 1907 and 1908. The plat arrangement was the same as in 1908. The unsprayed check vines were also in the same location as in 1908. (See fig. 21.) The same gasoline-engine spraying outfit was used as in the two previous seasons and the nozzle arrangement was also the same. A pressure of from 100 to 125 pounds was maintained and about 100 gallons of spray were applied per acre. The first application was made on Plats I and II June 8, just before the blossom buds opened. The second application was made June 28, after blossoming, when the berries were about the size of buckshot. At this date all four plats were sprayed. Plat II was given a double spraying on this date. The other plats received only one application at each date throughout the season. All four plats were sprayed July 9, when the berries were large enough to touch each other in the cluster. (See Table XXVII, showing spray formula and number of applications.)

TABLE XXVII.—*Spray formula and dates of applications against larvæ of the grape-berry moth. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

Plat No.	Spray formula.	Number of spray applications.	Date of application.
I	Three pounds arsenate of lead to 50 gallons of Bordeaux mixture.	3	June 8, 28; July 9.
II	do	3	Do.
III	do	2	June 28; July 9.
IV	do	2	Do.
Va,-*Vb*	Unsprayed		

Counts of infested berries were made on 25 vines in each of the unsprayed check plats and also in each of the sprayed plats. (See Table XXVIII, showing progress of infestation for season of 1909.)

TABLE XXVIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

FIRST COUNT OF INFESTED BERRIES, MADE ON JULY 25.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
I	June 8, 28, July 9	5–5–3–50	3	25	23
II	do	5–5–3–50	3	25	14
III	June 28, July 9	5–5–3–50	2	25	17
IV	do	5–5–3–50	2	25	12

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 21 TO 24.

I	June 8, 28, July 9	5–5–3–50	3	25	750
II	do	5–5–3–50	3	25	396
III	June 28, July 9	5–5–3–50	2	25	550
IV	do	5–5–3–50	2	25	390

FIG. 1.—SHOWING SIZE OF GRAPE BERRIES AT SECOND SPRAY APPLICATION ABOUT THE TIME MANY OF THE FIRST-BROOD EGGS OF THE GRAPE-BERRY MOTH ARE DEPOSITED ON THEM. (ORIGINAL.)

FIG. 2.—TRAILER METHOD OF VINEYARD SPRAYING IN ORDER TO APPLY THE SPRAY TO THE UNDERSIDE OF THE FOLIAGE OR TO THE GRAPE CLUSTERS WHERE THE FOLIAGE IS DENSE. (ORIGINAL.)

TABLE XXVIII.—*Progress of infestation of fruit by larvæ of the grape-berry moth in experimental plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909*—Contd.

FIRST COUNT OF INFESTED BERRIES, MADE ON JULY 25.

Plat No.	Date of spray application.	Spray formula.	Number of applications.	Number of vines examined.	Number of infested berries.
Va, Vb	Unsprayed	None	None.	25	34
Do	do	do	None.	25	28
Do	do	do	None.	25	21
Do	do	do	None.	25	19

SECOND COUNT OF INFESTED BERRIES, MADE ON SEPTEMBER 21 TO 24.

Va, Vb	Unsprayed	None	None.	25	1,574
Do	do	do	None.	25	890
Do	do	do	None.	25	468
Do	do	do	None.	25	1,168

The counts were made July 25 and September 21 to 24. The infestation this season, as in 1907 and 1908, was heavier on the south side of Plat I and on the east end of the east section and became lighter toward the north side and west end of the vineyard, a condition which existed throughout the three seasons.

When the crop was harvested it was found that there was practically no difference in weight of fruit per acre on the sprayed and the unsprayed vines. Taking the vineyard as a whole the infestation was very much lighter than in either of the preceding seasons. (See Table XXIX, showing percentage of infected berries on fruit from 25 vines in each of the sprayed and the unsprayed plats.)

TABLE XIX.—*Percentage of grape berries infested by larvæ of the grape-berry moth on 25 vines in sprayed and unsprayed plats. Vineyard of Mr. W. S. Wheeler, North East, Pa., 1909.*

SPRAYED.

Plat No.	Dates sprayed.	Number of times sprayed	Formula.	Number of vines examined.	Total number of clusters.	Average number of berries per cluster.	Number of infested berries.	Total number of berries.	Percentage of infested berries.	Date clusters were examined.
	1909.									
I	June 8, 28, July 9.	3	5-5-3-50	25	1,512	38	750	57,456	1.30	Sept. 21–24
II	do	3	5-5-3-50	25	1,242	38	396	47,196	.84	Do.
III	June 28, July 9.	2	5-5-3-50	25	1,203	38	554	49,514	1.12	Do.
IV	do	2	5-5-3-50	25	1,288	38	390	48,944	.79	Do.

UNSPRAYED.

Va, Vb	Unsprayed	None	None	25	1,102	38	1,574	42,256	3.72	Sept. 21–24
Va, Vb	do	do	do	25	994	38	890	37,772	2.36	Do.
Va, Vb	do	do	do	25	747	38	468	26,562	1.77	Do.
Va, Vb	do	do	do	25	1,182	38	1,168	44,916	2.60	Do.

In considering the results of the spray experiments presented in the foregoing paragraphs the casual reader might infer that the benefit derived does not offset the cost of the operation. Charging the total expense to this particular insect, this would probably hold true for the seasons of 1907 and 1909. The treatment for 1908 shows a cash increase in crop yield, however, which more than offsets the cost of spray treatment for that season. It should be remembered, too, that these spray applications serve to protect the grapevines against the grape rootworm and the fruit and foliage against fungous diseases. For both of these infestations it is desirable to make the spray applications at about the same dates that the applications are recommended to be made for the control of the larvæ of the grape-berry moth. Hence the additional expense involved in the increased amount of spray material used in making applications thorough enough to be effective in decreasing the infestation of the grape berries by this insect is not very great.

The cost of spray material and labor for each application at the rate of about 100 gallons per acre was approximately $2 per acre for each application. Furthermore, there is no doubt that the poison-spray application covering the three seasons greatly reduced the infestation throughout the vineyard, for at the end of the third season's treatment the infestation was manifestly much less than when the experiment was commenced.

RECOMMENDATIONS FOR CONTROL.

At the present state of our knowledge of the habits of this pest and of the methods that have been suggested and employed for its control it is impossible to recommend any one method which of itself has given results that are as satisfactory as could be wished. The life-history studies made during this investigation, which have been discussed under that head, indicate that we have been in error in assuming that there are three broods of this insect in the Lake Erie Valley. According to Prof. Slingerland the first brood develops in the blossom clusters and the recently set berries. The summer or second brood develops on the green grapes during July and early August and a partial third brood occurs in autumn.

On the strength of these statements much emphasis has been placed upon the importance and probable efficiency of a poison spray applied to the vines just previous to blossoming to destroy the larvæ of the first brood which feed upon the blossom cluster. The life-history studies made during this investigation, however, indicate that only about 25 per cent of the spring moths emerge previous and up to the time that the blossom buds break into bloom. Hence no matter how effective this first poison application may be in the destruction of the larvæ actually feeding upon the blossom

clusters it is ineffective against the larger portion of the first brood of larvæ, since at this time only a small portion of them have hatched. On the other hand, it is of great importance to destroy as many as possible of these early appearing larvæ, since the adults into which they develop deposit eggs for the second brood. With our present knowledge that the majority of the larvæ of this first brood do not appear until after the berries have set, this first poison application previous to blossoming can no longer be emphasized as the most important spray treatment, to the extent of regarding later applications as of little value or of withholding them entirely. In fact, with the knowledge that the majority of the larvæ hatch after the blooming period during the first two weeks in July, additional attention should be given to making the spray application very thorough during this period. It is quite probable that a single poison-spray application just before the blossom buds open, followed by a heavy double application about the first week in July just after the berries have set and at a time when the maximum number of larvæ are hatching, will doubtless give the most satisfactory results to be secured from a spray treatment. A study of the experimental results secured in the season of 1908, when this heavy double-application method was followed, indicates that better net results were secured from these double-spray applications than in the seasons of 1907 and 1909, when the plan of making a single application at each date of spraying was followed.

Where these heavy double-spray applications are resorted to it is suggested that a Bordeaux formula consisting of 3 pounds of lime and 3 pounds of copper sulphate to 50 gallons of water be employed instead of 5 pounds of lime and 5 pounds of copper sulphate as is sometimes recommended. The reason for suggesting this weakening of the Bordeaux formula is that injury to the foliage of the grape-vine has been observed to result from very heavy and frequent applications of the stronger formula.

In making spray applications against this insect it is very desirable that a high pressure be maintained in order to force the poison spray into the cluster so that all of the berries may be covered. (See Pl. VIII, fig. 1, showing size of grape berries at date of second spray application, at about the time many of the first-brood eggs of the grape-berry moth are deposited.) If at the second spraying this can not be done with a stationary nozzle arrangement on account of the dense foliage, the trailer method of application used against the grape leafhopper may be employed. (See Pl. VIII, fig. 2.)

When the grape leafhopper is at all numerous in vineyards where spraying treatment for the grape-berry moth is necessary, a combination spray may be used against both insects during the early part of July, using the "trailer" method of application.

Commercial tobacco extracts (blackleaf tobacco extract, containing $2\frac{7}{10}$ per cent nicotine sulphate) applied at a dilution of 1 to 150 gallons of water, or a still more highly concentrated form ("blackleaf 40," containing 40 per cent nicotine sulphate) applied at a dilution of 1 to 1,500 gallons of water, may be used with arsenate of lead. The tobacco extract is used on the leaf as a contact remedy against the nymphs of the grape leafhopper and the arsenate of lead on the fruit against the larvæ of the grape-berry moth. Paris green and arsenite of lime should not be mixed with the tobacco extracts as a substitute for arsenate of lead, for serious foliage injury results from these combinations.

The combination-spray application against these two insects should be made by the "trailer" method, as shown in Plate VIII, figure 2. The nymphs of the grape leafhopper suck the juice from the underside of the grape leaves and are killed by the tobacco extracts coming in contact with their bodies; hence, in making this application to the underside of the grape foliage most of the grape clusters are drenched by the spray. By the addition of arsenate of lead this application may also act as a treatment against the larvæ of the grape-berry moth.

Since no serious infections of black rot have occurred in the vineyards of the Lake Erie Valley during the past few seasons, the stronger fungicide formula does not appear to be necessary. Hence the combination spray formula recommended against this pest is as follows:

Lime	Bordeaux formula	pounds	3
Copper sulphate		do	3
Water		gallons	50
Arsenate of lead (insecticide)		pounds	3

Since the effectiveness of an arsenical spray treatment depends upon the presence of the poison upon the blossom clusters and upon the berries when the larvæ hatch from the eggs and commence to feed upon the blossom buds and berries, and since this period varies more or less each season, it is impossible to give definite dates at which the applications should be made. Hence the development of the blossom clusters and the formation of the berries will doubtless indicate more accurately the hatching period of the larvæ. The following spray schedule is based on the blossoming period of the grape and the development of the berries:

First application just previous to the blossoming period (see fig. 20) to poison the larvæ which feed in the blossom cluster, from about June 8 to 14.

The second application should be made immediately after blossoming, at which time the larvæ commence to feed upon the newly set berries, and the application should be doubled over those portions

of the vineyard where the infestation has been heavy during previous seasons. The time of this second application is approximately from June 20 to 30.

The third application should be made when the berries are about the size of buckshot (see Pl. VIII, fig. 1). If the foliage is dense, the "trailer" method of application should be employed, and if the grape leafhopper is at all numerous the tobacco extract should be added to control the latter insect. The time of this third application is approximately from July 5 to 15.

The poison-spray treatments recommended against the grape root-worm are also covered by the second and third applications against the grape-berry moth.

It should be distinctly understood by the vineyardist that the arsenate of lead is the active killing agent employed against the larvæ of the grape-berry moth and that it is applied with the Bordeaux mixture, which is a fungicide, in order to avoid the duplication of applications.

Where a considerable number of infested grape berries are observed on vineyard areas that received a poison-spray application before the grape blossoms opened, and a heavy double application after the berries had formed, it may be necessary to hand pick the infested berries during the latter part of July before many of the larvæ of the first brood have fully developed. By removing these larvæ from the vineyard and destroying them by immersing the infested berries in boiling water, the amount of infestation by the second brood of larvæ may be greatly reduced.

Should only limited areas of the vineyard prove to be seriously infested at the approach of the picking season, as frequently occurs, it is suggested that the vineyardist remove the fruit from these vines as early as possible, for in doing so he may be able to remove a good many of the larvæ from the vineyard which would otherwise remain there to reinfest the crop of the succeeding season.

In addition to the control methods suggested against the larvæ, special effort should be made to destroy the pupæ which pass the winter in the fallen leaves, on the ground beneath the trellis. (See fig. 22.) As previously mentioned, observations made during this investigation indicate that the majority of the pupæ over-winter in cocoons made upon leaves which have fallen prematurely to the ground beneath the trellis. These leaves are frequently stuck to the soil and are in a state of semidecay before the rest of the foliage has fallen from the vines. Hence there is little likelihood that many of these leaves bearing the cocoons will be blown out of the vineyard. For this reason it is quite probable that if 2 or 3 inches of soil are thrown under the trellis in late fall or early spring many of the pupæ may be destroyed by this operation. It is not known positively that

plowing under the pupa-infested leaves in this manner will destroy the insect in this stage, but it is highly probable that many fatalities will result from the method. It is believed that greater success will result from an endeavor to destroy the pupæ which are in cocoons upon leaves that remain in the vineyard throughout the winter than in the destruction of leaves outside of the vineyard which are blown into fence rows, ditches, and adjacent rough lands. No moths of this insect have been reared from grape leaves gathered from these latter locations, although several attempts have been made to secure specimens from them.

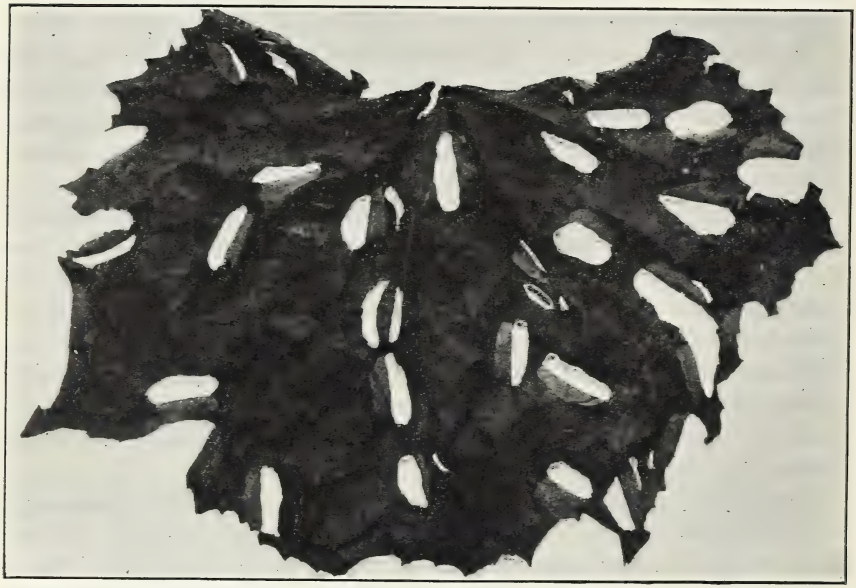

FIG. 22.—Overwintering cocoons of the grape-berry moth upon leaf on ground, beneath a badly infested grapevine. (Original.)

CONCLUSION.

Wherever vineyards have become badly infested by the grape-berry moth serious injury to the crop has resulted and the owners of the infested vineyards have found it a very difficult pest to eradicate. Many vineyardists who have tried to control the pest with a poison spray have not met with as complete success as they would wish. Many such instances of complete or partial failure have been observed. In nearly all of these cases, however, investigation has shown that this lack of success, in all probability, was largely due, either to inferior spraying equipment which failed to deliver the spray in sufficient quantity and force to thoroughly cover the clusters, or to the fact that the applications were not made at a time when the majority of the larvæ were about to hatch. Frequently both of these condi-

tions have occurred simultaneously, and as a result, failure has been complete. For this reason the spray method of control is looked upon with disfavor by many who have carried on the work under these conditions.

In vineyards where infestation is at all serious vineyardists are urged to give the spray method a thorough trial for a period of several consecutive seasons. If the infestation is confined to a limited area, as is frequently the case, the owner can well afford to make additional applications over this area to prevent it from increasing and spreading farther into the vineyard and possibly, at some future time, causing the loss of a large percentage of the crop over the entire area.

A lack of knowledge of the extent of the infestation of his vineyard by this pest during the early stages of the first brood is perhaps one of the chief causes for lack of successful control by the owner. It is hoped that with the aid of the data contained in this paper under "Seasonal history" the vineyardist will be better able to determine the periods when the maximum number of larvæ leave the eggs to enter the berries, and with the additional aid of more efficient high-pressure power-spraying machinery now available for this work it is believed that the poison-spray method of control will prove to be the most effective and practical means of controlling this pest.

Combination spray mixtures, whereby other insect pests of the grapevine can be controlled by the same applications made against the grape-berry moth, have been suggested under the head of recommendations for control and are worthy of trial in the endeavor to reduce the cost of controlling several of the pests that infest the fruit and foliage of the grape in the vineyards throughout the Lake Erie Valley. This phase of control work will receive some attention in connection with further studies to be made of grape pests, by the Bureau of Entomology, in this region.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE CHERRY FRUIT SAWFLY.

(*Hoplocampa cookei* [Clarke]).

By S. W. Foster,

Entomological Assistant.

INTRODUCTION.

The cherry fruit sawfly is an insect comparatively little known to science. It was first described by Prof. W. T. Clarke in the Canadian Entomologist, volume 38, No. 11, page 353, under the name *Dolerus cookei*. In 1910 specimens of this species were brought to the attention of Mr. S. A. Rohwer, of the Bureau of Entomology, who referred it to the genus Hoplocampa. As he was unfamiliar with the type of *cookei*, he considered that it represented an undescribed species, for this latter was destroyed in the insect collections by the San Francisco fire. Mr. Rohwer, however, as a result of the examination of abundant material, has come to the conclusion that his and Clarke's species are the same insect, which should now be known under the name of *Hoplocampa cookei* (Clarke). Mr. Rohwer's description of the species as *Hoplocampa californica* is given herewith, as taken from Technical Series No. 20, Part IV, of this bureau, page 143:

Female.—Length 3.5 mm. Clypeus broadly, shallowly, angulately emarginate, lobes broad, obtusely triangular; supraclypeal area convex, finely granular; antennal furrows wanting, antennal foveæ small; middle fovea elongate, shallow, not well defined; ocellar depression small, distinct, not sharply defined; postocellar area well defined on all sides; head and mesoscutum with small, separate, well-defined punctures; antennæ rather slender, third and fourth joints equal; sheath slightly concave above, slender, convex below from apex; cerci short, stout; stigma broadest near base, strongly tapering to apex; transverse radius strongly oblique, in apical third cell; third cubital cell longer than first and second combined. Black; clypeus, labrum, mandibles (except piceous apices), orbits, occiput (except postocellar), tegulæ, anterior legs (except coxæ), intermediate femora, and part of posterior femora reddish yellow; posterior femora in part, most of four hind tibiæ, and tarsi black or brownish; wings hyaline, iridescent; venation pale brown, stigma in part pallid.

Paratopotypes show that the four hind legs may be mostly black, the posterior orbits pale and the pale spots of the occiput reduced in size.

Male.—Length 3 mm. Clypeus more obtusely emarginate than in female; third joint shorter than fourth; stigma not strongly tapering; hypopygidium narrowly rounded at apex. Black; antennæ, head (except interocellar area), margin of mesoprescutum, lati, pectus, legs, and venter reddish yellow; wings as in female.

Type locality.—Suisun, Cal., March 10, 1910 (R. W. Braucher); eight females and one male.

Type.—Catalogue No. 13471, U. S. National Museum.

On April 20, 1909, while inspecting the cherry orchard of Mr. Charles Barnes, Suisun, Cal., for the extent of injury caused by the pear thrips, the writer found several cherries infested with small white hymenopterous larvæ. The full-grown larvæ were about five-sixteenths of an inch long and apparently did most of the feeding inside of the kernel, or in the flesh immediately adjoining the kernel. Although the cherry crop was light the injury was quite general, and further search on April 25 showed the little larvæ in greater or less numbers in most of the cherry orchards of the Suisun Valley. A large series of counts made of the fruit in Mr. Barnes's orchard showed approximately 80 per cent of the fruit to have been injured by these larvæ.

At this latter date, April 25, most of the larvæ were full grown. Some had evidently finished feeding and had left the fruit. However, careful search in the ground under the trees failed to show the presence of any larvæ or pupæ. A large quantity of infested fruit (See Pl. IX, figs. 1, 2) was taken to the laboratory for further study and life-history observations.

SEASONAL HISTORY AND HABITS.

All of the larvæ in the rearing cages had left the fruit and had gone into the soil in the bottom of the cages by May 5, 1909. None of them pupated among the sticks and trash which had been placed in the cages on top of the soil. The cages were sunk in the ground to approach as nearly as possible the normal out-of-doors conditions. Unfortunately all of these larvæ were killed by drainage water from a near-by sink seeping into the cage during the absence of the writer.

In June, 1912, the writer received from Mr. P. J. O'Gara, Medford, Oreg., a consignment of cherries showing the characteristic injury caused by this species. Mr. O'Gara stated that he had observed the larvæ in a few orchards in one locality in Jackson County, Oreg., and that this insect also attacked prunes.

So far as the writer has learned this is the only occurrence of the cherry fruit sawfly outside of the State of California.

THE ADULT.

Close watch was kept in the spring of 1910 for the first appearance of adults in the field. Mr. R. W. Braucher, who was detailed to look after the demonstration spraying for pear thrips in that locality

for the Bureau of Entomology, kept a close watch for the first appearance of the adults of this species. On March 10, 1910, he found three female sawflies (see fig. 23, *d*) in cages planted under trees in the orchard and used for the emergence records of the pear thrips. Four more adults were caught in the cages on March 12, and two dead ones were found outside of the cages. These had evidently been killed by the spraying for thrips the previous morning. The first males were found March 16 and after this date both sexes were quite numerous for some two weeks or more. The Black Tartarian cherries were just beginning to bloom at this time.

The writer spent considerable time in the Suisun section at this period, making a further study of the life history and habits of the

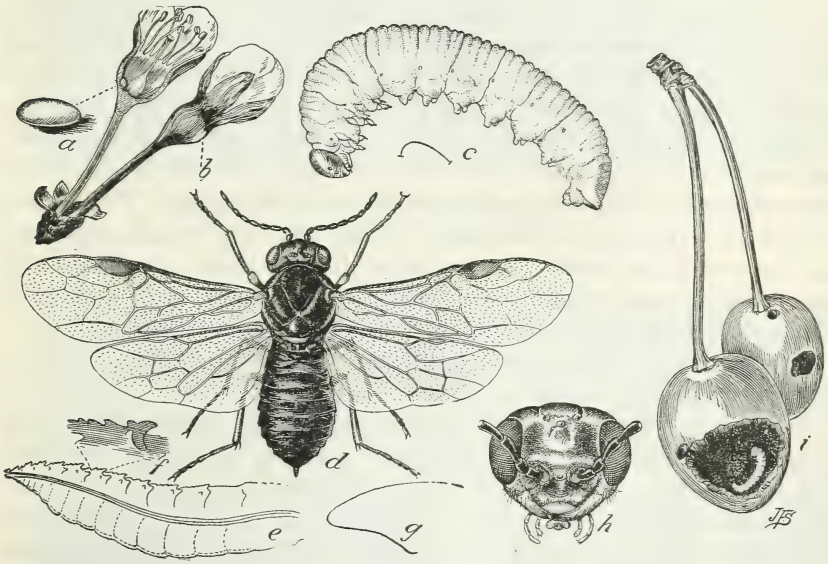

FIG. 23.—Stages and work of the cherry fruit sawfly (*Hoplocampa cookei*): *a*, Egg; *b*, position of egg in cherry blossom; *c*, larva; *d*, adult sawfly; *e*, saw of ovipositor; *f*, serrations on ovipositor; *g*, sheath of saw; *h*, head of adult sawfly; *i*, infested cherries. (Original.)

insect. By March 20 adults of both sexes were plentiful, but the females far outnumbered the males. As many as 40 individuals were observed in one tree, two-thirds to three-fourths of which were females. The adults were very sluggish in the early mornings and could be picked up with little or no difficulty. Toward noon, as the atmosphere grew warmer, they became more active, but even then many individuals could be caught in the trees. The adults may be found resting on the leaves, leaf stems, blossoms, both outside and inside, and on the twigs. A few were observed feeding on the nectar of the more advanced flowers. In confinement the adults fed quite freely upon sirup and water.

Egg laying had begun only sparingly on March 21, but by the afternoon of March 23 many eggs could be found. A thorough search in three different orchards failed to show any larvæ. Oviposition was at its height about March 23 to 30, and was practically over by April 5, the adults having mostly disappeared by this time. The females seem to die off in advance of the males, showing about the same comparative difference as was the case at the beginning of the emergence. On April 3 and 4 as high as eight males to one female were noted. On April 6, two orchards were closely examined, and while many males were in evidence not one female could be found.

THE EGG.

Egg laying began in 1910 about March 16, just as the Black Tartarian cherries were beginning to open first blossoms. The females oviposit quite freely in the orchards, always on blossoms just about ready to spread the petals. (See Pl. X, fig. 1.) The greater number of eggs are deposited in the sepals of the flower, although some are deposited in the upper portion of the calyx cup, but only in rare cases are any eggs deposited below the middle of the calyx cup. The female inserts her ovipositor in the tissue, usually from the outside, making, for the size of the insect, a rather large, deep incision and placing the egg in the opening just made. The egg is usually placed at such depth that it can be seen from the opposite side of the sepal.

The egg (fig. 23, *a*) is 0.5 mm. long by 0.3 mm. wide, whitish, slightly shiny, and somewhat kidney-shaped.

Incubation.—Of a total of 35 eggs deposited between 8 a. m. March 21 and 8 a. m. March 22, 27 had hatched by 8 a. m. March 25, the others hatching during the day. Another batch of four eggs, deposited March 25, hatched March 30. There were three other observations in which the eggs hatched in five days after oviposition. Mr. Braucher reports another instance of eggs that were deposited on March 28 hatching in the afternoon of March 31. The summary of these records together with many field observations shows the length of time required for incubation to vary from three to six days, averaging from four to five days. This time is influenced by temperature conditions, as eggs kept indoors required from 18 to 36 hours longer than eggs kept outside. The time of hatching coincides very closely with the falling of the petals from the blossoms of the variety attacked. Usually the eggs are deposited at or just prior to the opening of the petals and hatch with the falling of the petals. One very interesting observation was that the adults invariably deposit their eggs at this stage of blossom development regardless of the variety. In one

FIG. 1.—CHERRIES INJURED BY THE CHERRY FRUIT SAWFLY (HOPLOCAMPA COOKEI). TWICE NATURAL SIZE. (ORIGINAL.)

FIG. 2.—ENTRANCE AND EXIT HOLES OF THE CHERRY FRUIT SAWFLY. NATURAL SIZE OR TWICE NATURAL SIZE. (ORIGINAL.)

WORK OF CHERRY FRUIT SAWFLY LARVÆ IN IMMATURE CHERRIES.

FIG. 1.—CHERRY BLOSSOM CLUSTERS AT STAGE OF DEVELOPMENT WHEN MOST OF THE EGGS OF THE CHERRY FRUIT SAWFLY ARE BEING DEPOSITED. ABOUT TWICE NATURAL SIZE. (ORIGINAL.)

FIG. 2.—LARVÆ AND COCOONS OF THE CHERRY FRUIT SAWFLY. ABOUT FOUR TIMES NATURAL SIZE. (ORIGINAL.)

orchard under observation there were early and late blooming cherries in alternating rows. Eggs of this insect were numerous and a few larvæ present before the adults apparently noticed the later-blooming varieties. Afterwards, when the petals of the Royal Anne cherry were beginning to open, eggs were just being deposited in numbers in this variety while the Black Tartarians immediately adjoining these trees had shed the petals and the larvæ had mostly hatched and only very rarely could an egg be found. The time required for incubation of the egg is practically the same in all varieties of fruits. Ordinarily only one egg is deposited in a single flower. Occasionally, however, two and very rarely three eggs were found in the sepals and calyx of one flower.

THE LARVA.

Upon hatching the young larva may feed for a short time in the tissue immediately surrounding the egg cavity, or on the inner surface of the calyx cup, but it soon finds its way to the bottom of the calyx cup and eats directly into the newly formed cherry. The larva at this time almost always enters the fruit through the base immediately adjoining or very near the stem. Going directly to the center of the cherry, the larva eats away the small kernel. The cherry thus injured soon withers. In two to four days after entrance the larva makes its first molt and leaves this cherry in search of other and fresh food. When attacking the second cherry the larva may enter the fruit through almost any place on the surface but invariably goes directly to the seed, and if this has not hardened eats out the kernel, as was done with the first fruit, seeming to prefer this to the meat of the cherry. The second cherry, being larger when attacked, usually withstands the effects of feeding longer and the larva may remain inside for some six to ten days or even longer. The growth of the cherry is checked and it frequently hangs on the tree retaining a rather pale green color for some days after growth ceases and the fruit has shriveled. When the kernel in this second cherry has been destroyed the larva usually goes to a third cherry and if the pit has not hardened eats it out as before. However, when the pits become too hard the larva feeds on the meat of the cherry near the pit until it attains full growth in much the same manner as does the plum curculio in peaches. In Plate IX are shown photographs of the injured fruit and the entrance and exit holes of the larvæ.

Each larva usually destroys three cherries, although some go to the fourth, while a very few complete their growth in the second cherry. The time required for the larvæ to attain their full growth averages from 22 to 26 days. In Table I the record is given for 34 individuals.

TABLE I.—*Length of larval stage of the cherry fruit sawfly, Suisun, Cal., 1910.*

Date.	Observation.
1910.	
Mar. 25..	34 larvæ hatched in cherry blossoms in cage.
Mar. 27..	Supply of fresh food given (branches of young fruit from cherry tree).
Mar. 30..	24 larvæ had entered second cherry.
Apr. 1...	6 more larvæ had entered second cherry.
Apr. 6...	Fresh food put into cage.
Apr. 8...	16 larvæ found in third cherry; 6 larvæ still in second cherry.
Apr. 12..	Fresh food put into cage.
Apr. 16..	3 full-grown larvæ left fruit.
Apr. 17..	2 full-grown larvæ left fruit.
Apr. 18..	5 full-grown larvæ left fruit.
Apr. 19..	Do.
Apr. 20..	3 full-grown larvæ left fruit and 5 full-grown larvæ found in trash at bottom of cage. All the larvæ had left fruit at this date.

When full grown (see fig. 23, *c*) the larva leaves the fruit and works its way into the ground, where it constructs a small parchment-like cocoon. The cocoon will be found from 3 to 7 inches below the surface, the depth varying somewhat with the texture of the soil. It is elliptical or oval in shape and from one-fourth to three-eighths of an inch long. Inside the cocoon is smooth, dark brown in color, of a papery texture, and somewhat brittle, especially in dry soil, so that it is easily broken. The outer surface of the cocoon is covered with fine particles of soil, giving it the appearance of a small clod of dirt. In Plate X, figure 2, are shown full-grown larvæ and cocoons, some of the latter being torn partly open.

FIG. 24.—*Microbracon* sp., a hymenopterous parasite of the cherry fruit sawfly (*Hoplocampa cookei*). (Original.)

The larva remains as such in the cocoon until the following winter. Some time after the winter rains begin it transforms to pupa and emerges the following March as adult.

The pupa has not been observed. There is only one brood each year.

NATURAL ENEMIES.

Two parasites, an ichneumon and a microbracon (see fig. 24), were obtained from the material collected by Mr. Braucher.

Several large collections of infested fruit were brought to the laboratory for possible parasites, but none was obtained from this

material. It is possible that this species is rather heavily parasitized at times. The insect has been known in the Suisun Valley since 1905, but caused comparatively little injury from that time until the serious outbreak of 1909. As no spraying had been done in the infested orchards that would be of any value as a control to this particular species it would seem that the parasites, together with more thorough cultivation, have served to keep it fairly well in check. The insect was less numerous in 1910 than in 1909 and the same was true of the years 1911 and 1912.

EXPERIMENTS IN CONTROL.

Experiments in spraying with arsenate of lead were made in 1910, but in this instance the poison did not prove to be altogether effective. Some larvæ were killed, but not enough to warrant the recommendation of this as a satisfactory treatment in case of a serious outbreak of the insect. Further work along this line is desirable. Mr. O'Gara, in a letter, reports satisfactory results from the use of arsenate of lead in the Rogue River Valley of Oregon.

Many adults were killed in the early mornings while spraying with 3 per cent distillate-oil emulsion to which sulphate of nicotine had been added at the rate of 1 part to 2,000 parts of water. This method would most likely be a very effective means of control if all the spraying could be done in the early morning. At this time the adults are very sluggish and can be easily wet with the spray.

Perhaps a more likely means of holding this sawfly in check is by careful cultivation. The most serious hindrance to this plan of treatment in cherry orchards is that the roots of the cherry tree close to the trunk are near the surface, and some larvæ go below the top of these roots. However, it is highly advisable to cultivate the land thoroughly two or three times just prior to the first picking of the Black Tartarian cherries, as most of the larvæ are leaving the trees at this time and numbers of them would probably be killed.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

LIME-SULPHUR AS A STOMACH POISON FOR INSECTS.

By E. W. Scott and E. H. Siegler,
Entomological Assistants, Deciduous Fruit Insect Investigations.

INTRODUCTION.

During the season of 1912 the branch of Deciduous Fruit Insect Investigations of the Bureau of Entomology, at its laboratory at Benton Harbor, Mich., conducted a series of feeding experiments to test the killing effect of various poisons on different species of insects. In the course of the work it was soon noted that lime-sulphur, when combined with certain slow-acting arsenicals and doubtful stomach poisons, increased their insecticidal value. This clue was followed up and a considerable series of feeding tests was made during the succeeding months. These experiments indicate that lime-sulphur spray alone, at the strength used in spraying orchards in foliage, has a decided insecticidal action as a stomach poison. It will be remembered that lime-sulphur as an insecticide has been heretofore considered solely as a contact spray. In this paper are given the results obtained from the use of lime-sulphur and arsenate of lead, separately and in combination.

CONDITIONS OF THE EXPERIMENTS.

The fall webworm (*Hyphantria cunea* Drury) (see Plate XI) was used for most of the feeding tests, since this insect was readily obtained in large numbers. Furthermore, it was easily handled, was rather resistant to poisons, and on the whole proved an ideal species for the work at hand. The stock supply was collected in the field and brought to the laboratory where the tests were made. Only the very young larvæ, usually three or four days old, were used, and whenever possible those from the same nest were used for the same experiment. When two or more nests of larvæ were necessary for use in a given experiment, care was taken to use those of as nearly the same age as possible.

The wild black cherry (*Prunus serotina*) was found to be a favorite food plant of the fall webworm in Michigan. In addition, the foliage stood up well when the branches were placed in water, and, further,

was rather resistant against the burning effect of the spray materials. Twigs bearing from 20 to 30 leaves were employed.

The spray was applied to the foliage by means of a large atomizer of the type in which quart jars are used as a container for the liquid. The twigs were sprayed until the leaves began to drip, approaching as nearly as possible the conditions of field spraying operations. Each sprayed twig was then placed in a jelly glass of water, the stem extending through a hole punched in the tin cover. (See Plate XI, figs. 1, 2.)

After the spray had thoroughly dried, allowing from 6 to 12 hours, 20 insects were placed on the leaves of each twig. A large paper bag was then placed over the twig and held to the glass by means of a rubber band. (See Plate XI, fig. 1, at right.)

Observations were usually made every other day; in some cases every day. At each examination the bag was removed and the dead larvæ taken out and counted. When all the insects were dead, or had pupated, as the case might be, the amount of foliage consumed was measured in square inches. A sheet of celluloid cross-sectioned to one one-hundredth of a square inch was utilized for this purpose. These measurements were easily taken, where effective poisons were used, as the young larvæ died before very much foliage had been consumed. The younger larvæ ate only one surface of the leaf, but as they increased in size the leaves were often skeletonized. Owing to this fact it became necessary to differentiate between the one and two surface feedings. Therefore, in order to equalize these conditions, the measurements of the one surface feeding were divided by two. Another difficulty in securing feeding measurements in the case of unsprayed twigs used as checks was encountered when the entire leaf, except the midrib and larger veins, was consumed. In such instances the outline of the leaf was nearly obliterated, thus rendering actual measurements in the ordinary way impossible. However, since the leaves of the wild cherry selected for the experiments were fairly uniform in size, this difficulty was overcome by taking the measurement of an average-size leaf and substituting it for the leaf the outline of which had been destroyed. This method gave approximately accurate results. Careful attention was given to the condition of the foliage throughout the experiments so as to supply the larvæ with palatable food at all times. It was seldom necessary, however, to renew the foliage, except for the unsprayed lots, which were quickly devoured.

Commercial lime-sulphur testing 33° Baumé was used at strengths varying from $\frac{1}{4}$–50 to 6–50.[1] In lots 4 and 5 of Table VI home-boiled lime-sulphur testing 30° Baumé was used at the rate of $1\frac{1}{2}$–50.

[1] All the strengths indicated as above signify a given quantity of poison diluted with water to make a total of 50 gallons of spray material. For example, lime-sulphur, $1\frac{1}{2}$–50, means $1\frac{1}{2}$ gallons concentrated lime-sulphur solution diluted with water to make 50 gallons of spray material. Arsenate of lead, 2-50, means 2 pounds arsenate of lead diluted with water to make 50 gallons of spray material.

Arsenate of lead at strengths varying from ½–50 to 5–50 was used in comparison with the lime-sulphur solution. Arsenate of lead and lime-sulphur were also used together at various strengths (Tables I and IV). In the case of the arsenate of lead and the lime-sulphur most of the feeding was done during the first three or four days. However, in no instance was there much feeding during the first 24 hours, as the larvæ were more or less unsettled until they found a suitable place for their web. This was true on the unsprayed as well as the sprayed leaves.

It will be found in the following pages that the rate of killing is fairly uniform in all experiments. Since, however, the tests were conducted throughout the season under different climatic conditions, slight variations exist.

RESULTS.

Experiment I.

The results given in Table I are taken from an experiment to obtain data on the killing effect on the fall webworm of various chemicals combined with lime-sulphur. Lot 1 was the unsprayed check; lot 2 was sprayed with lime-sulphur alone at the strength of 1½–50, and lot 3 with lime-sulphur, 1½–50, in combination with arsenate of lead, 2–50. In the course of a few days it was observed that several larvæ on the lot sprayed with lime-sulphur were dying. The 20 larvæ of this lot were dead at the end of 13 days, as against 7 days required to kill all the larvæ with the combination of arsenate of lead and lime-sulphur. On the unsprayed lot, at the end of 72 days, 4 larvæ were recorded dead, 12 had pupated, and 4 were missing.

Table I.—*Tests of the killing effect on the fall webworm of lime-sulphur alone and combined with arsenate of lead.*

[Experiment started July 20, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.			Date of examination.	Larvæ dying in each lot.		
	Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1½–50.	Lot 3—Lime-sulphur, 1½–50, and arsenate of lead, 2–50.		Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1½–50.	Lot 3—Lime-sulphur, 1½–50, and arsenate of lead, 2–50.
July 22	1			Aug. 12			
23				14			
24			1	16			
25			7	18			
26		4	10	21			
27		3	2	23			
28		3		Sept. 2	1		
29		4		19	2		
30				30			
31		4					
Aug. 1				Total number dead	4	20	20
2		2		Number of days required to kill		13	7
3				Square inches of foliage consumed	243.20	0.73	0.12
4							
6							
9							

EXPERIMENT II.

In order to obtain further data on the killing effect of lime-sulphur another experiment was started July 30, using different strengths of lime-sulphur as given in Table II.

TABLE II.—*Tests of the killing effect of lime-sulphur on the fall webworm.*

[Experiment started July 30, 1912, Benton Harbor, Mich.; 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.					Date of examination.	Larvæ dying in each lot.				
	Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1½–50.	Lot 3—Lime-sulphur, 3–50.	Lot 4—Lime-sulphur, 6–50.	Lot 5 [1]—Arsenate of lead, 2–50.		Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1½–50.	Lot 3—Lime-sulphur, 3–50.	Lot 4—Lime-sulphur, 6–50.	Lot 5 [1]—Arsenate of lead, 2–50.
Aug. 1						Aug. 14		2			
2						15					
3		2				20					
4			1	3		25					
5		1	1	5	6	29					
6				3							
7	1	1	9	8		Total number dead	1	20	20	20	20
8		3	4	1	14	Number days required to kill		15	12	9	9
9		2	4			Square inches foliage consumed	40.00	1.21	0.65	0.34	0.83
10		2									
11		4	1								
12		1									
13		2									

[1] Arsenate of lead was used in lot 5 for comparison with the lime-sulphur solution.

In this experiment 15 days were required by lime-sulphur, 1½–50, to kill the 20 larvæ, as against 9 days required by arsenate of lead, 2–50. Twelve days were required by lime-sulphur, 3–50, while lime-sulphur, 6–50, killed the 20 larvæ in the same length of time required by arsenate of lead, 2–50. The check lot was discontinued at the end of 30 days, when 1 larva was recorded dead and 40 square inches of foliage consumed. It was found in this test that the number of square inches of foliage consumed decreased about one-half as the strength of the lime-sulphur was doubled, the largest amount being 1.21 square inches. The amount consumed on the arsenate-of-lead lot was 0.83 of a square inch.

EXPERIMENT III.

In Table III are shown the comparative results of a dosage test consisting of seven different strengths of lime-sulphur varying from ½–50 to 6–50, and four different strengths of arsenate of lead varying from ½–50 to 5–50.

FIG. 1.—AT LEFT, SPRAYED TWIG OF WILD CHERRY, SHOWING LARVÆ OF THE FALL WEBWORM (HYPHANTRIA CUNEA) FEEDING ON LEAVES; AT RIGHT, SAME, COVERED WITH PAPER BAG TO PREVENT ESCAPE OF LARVÆ. (ORIGINAL.)

FIG. 2.—UNSPRAYED TWIG OF WILD CHERRY UPON WHICH FALL WEBWORMS HAVE BEEN FEEDING FOR SOME TIME; FOR COMPARISON WITH SPRAYED TWIG. (ORIGINAL.)

PLATE XI.

METHOD OF TESTING LIME-SULPHUR AS A STOMACH POISON AGAINST THE FALL WEBWORM.

TABLE III.—*Tests of the killing effect on the fall webworm of lime-sulphur in comparison with arsenate of lead.*

[Experiment started August 8, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.											
	Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1/2–50.	Lot 3—Lime-sulphur, 1–50.	Lot 4—Lime-sulphur, 1 1/2–50.	Lot 5—Lime-sulphur, 2–50.	Lot 6—Lime-sulphur, 3–50.	Lot 7—Lime-sulphur, 5–50.	Lot 8—Lime-sulphur, 6–50.	Lot 9—Arsenate of lead, 1/2–50.	Lot 10—Arsenate of lead, 1–50.	Lot 11—Arsenate of lead, 2–50.	Lot 12—Arsenate of lead, 5–50.
Aug. 10	.....	.....	.....	.....	.....	.....	.....	2	.....	2	8	4
12	.....	.....	.....	.....	.....	.....	1	3	.....	2	11	15
14	.....	1	4	5	2	3	6	11	1	10	1	1
16	.....	3	8	13	6	6	6	4	11	2	.....	.....
18	.....	2	8	2	8	11	7	.....	3	4	.....	.....
20	.....	8	.....	.....	4	.....	.....	.....	4	.....	.....	.....
22	.....	6	.....	.....	.....	.....	.....	.....	1	.....	.....	.....
Sept. 2	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Oct. 19	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total number dead	7	20	20	20	20	20	20	20	20	20	20	20
Number days required to kill	.....	14	10	10	12	10	10	8	14	10	6	6
Square inches of foliage consumed	119.00	3.92	0.36	0.17	1.01	0.81	0.73	0.26	2.38	1.98	0.11	0.10

It will be noted that lime-sulphur, 1/2–50, killed the 20 larvæ in 14 days, the same length of time required by arsenate of lead, 1/2–50. Also lime-sulphur, 1–50, killed the larvæ in the same length of time as arsenate of lead 1–50, the time required being 10 days. However, in both instances the arsenate of lead killed more rapidly in the beginning than the lime-sulphur. Eight days were required by lime-sulphur, 6–50, to kill the 20 larvæ as against 6 days required by arsenate of lead, 5–50. The amount of feeding varied somewhat in this experiment, the largest amount on the sprayed lots being 3.92 square inches where lime-sulphur, 1/2–50 was used, and the smallest amount being 0.10 of a square inch in lot 12 which was sprayed with arsenate of lead, 5–50.

EXPERIMENT IV.

The object of experiment IV was to obtain data on the relation of the killing effect of arsenate of lead alone and combined with lime-sulphur, and to obtain, if possible, data on the effect the addition of one to the other has upon the rapidity of killing. Lime-sulphur alone was used at four different strengths, and also was combined at the same rates with arsenate of lead, 2–50. The lime-sulphur strengths employed were 1/4–50, 3/4–50, 1 1/2–50, and 3–50. Arsenate of lead, alone, was tried out at strengths of 1/2–50, 1–50, 2–50, 3–50, and 5–50, and also at the same strengths was combined with lime-sulphur, 1 1/2–50. The results are given in Table IV.

TABLE IV.—*Tests of the killing effect on the fall webworm of lime-sulphur and arsenate of lead, alone and combined.*

[Experiment started Aug. 19, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.									
	Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1/4–50.	Lot 3—Lime-sulphur, 3/4–50.	Lot 4—Lime-sulphur, 1 1/2–50.	Lot 5—Lime-sulphur, 3–50.	Lot 6—Arsenate of lead, 1/2–50.	Lot 7—Arsenate of lead, 1–50.	Lot 8—Arsenate of lead, 2–50.	Lot 9—Arsenate of lead, 3–50.	Lot 10—Arsenate of lead, 5–50.
Aug. 21			1		3		3	4	5	12
23		1	2	2	2	2	10	2	13	8
25		2	1	8	9	8	7	14	2	
27		8	7	10	6	7				
29		8	7			3				
31		1	2							
Sept. 2										
4										
6										
8										
10										
15	3									
Oct. 3	5									
Total number dead	8	20	20	20	20	20	20	20	20	20
Number days required to kill		12	12	8	8	10	6	6	6	4
Square inches of foliage consumed	72.00	3.51	2.87	0.17	0.49	2.44	0.36	0.57	0.24	0.02

Date of examination.	Larvæ dying in each lot.							
	Lot 11—Lime-sulphur, 1 1/2–50; arsenate of lead, 1/2–50.	Lot 12—Lime-sulphur, 1 1/2–50; arsenate of lead, 1–50.	Lot 13—Lime-sulphur, 1 1/2–50; arsenate of lead, 2–50.	Lot 14—Lime-sulphur, 1 1/2–50; arsenate of lead, 5–50.	Lot 15—Arsenate of lead, 2–50; lime-sulphur, 1/4–50.	Lot 16—Arsenate of lead, 2–50; lime-sulphur, 3/4–50.	Lot 17—Arsenate of lead, 2–50; lime-sulphur, 1 1/2–50.	Lot 18—Arsenate of lead, 2–50; lime-sulphur, 3–50.
Aug. 21			3	10	9	5	1	6
23	2	14	9	10	9	11	6	9
25	8	4	7		2	4	13	5
27	6	2	1					
29	4							
31								
Sept. 2								
4								
6								
8								
10								
15								
Oct. 3								
Total number dead	20	20	20	20	20	20	20	20
Number days required to kill	10	8	8	4	6	6	6	6
Square inches of foliage consumed	0.52	0.02	0.28	0.07	0.30	0.19	0.06	0.22

None of the larvæ on the unsprayed lot died until September 15, 27 days after the experiment was started. On October 3 the records of this lot showed 8 dead, 6 pupated, and 6 missing. Lime-sulphur alone, 1/4–50, and likewise 3/4–50, killed all the larvæ in 12 days, while the time required by strengths of 1 1/2–50 and 3–50 was 8 days in each case, the rapidity of killing being somewhat greater with the latter strength. Arsenate of lead alone, 1/2–50, killed the 20 larvæ in 10 days, or 2 days more than was required by lime-sulphur, 1 1/2–50. Arsenate

of lead, 1–50, 2–50, and 3–50, each killed the larvæ 2 days sooner than that required by lime-sulphur, 1½–50. Lime-sulphur, 1½–50, when added to the various strengths of arsenate of lead did not appreciably affect the rate of killing of the arsenate of lead. The amount of feeding was reduced in all cases, excepting that of the strongest solution, lot 14, by the addition of lime-sulphur.

On the lots sprayed with lime-sulphur, ¼–50, ¾–50, 1½–50, and 3–50, combined with arsenate of lead, 2–50, there was no difference in the length of time required to kill the larvæ, 6 days being required in all cases. The same number of days was required by arsenate of lead alone, 2–50, but the rapidity of killing was somewhat increased by the addition of lime-sulphur.

Experiment V.

In an experiment to obtain data on the sticking qualities of various sprays, three lots of the regular orchard demonstration strength of lime-sulphur, 1½–50, were used. The three lots were thoroughly sprayed and allowed to dry. One lot was then washed for 15 minutes under a shower bath, by placing the twig just above the floor in an inclined position, allowing the water to fall upon it. Another lot was washed 30 minutes in the same manner, while the third lot remained unwashed.

The same procedure was carried out on three lots of arsenate of lead, 2–50. After the twigs were again thoroughly dry 20 larvæ were placed on each. The results of this experiment are to be found in Table V.

Table V.—*Tests of the killing effect of lime-sulphur in comparison with arsenate of lead after washing of each.*

[Experiment started August 4, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.						
	Lot 1—Check (unsprayed).	Lot 2—Lime-sulphur, 1½–50; not washed.	Lot 3—Lime-sulphur, 1½–50; washed 15 minutes.	Lot 4—Lime-sulphur, 1½–50; washed 30 minutes.	Lot 5—Arsenate of lead, 2–50; not washed.	Lot 6—Arsenate of lead, 2–50; washed 15 minutes.	Lot 7—Arsenate of lead, 2–50; washed 30 minutes.
Aug. 7					1		
9					7	2	
11		2		1	12	4	
13		2	2	2		5	1
15		12	9	8		9	2
17	1	4	7	9			7
19			2				4
21							4
29	2						
Sept. 9	3						
19	1						
Total number of dead	7	20	20	20	20	20	[1] 18
Number of days required to kill		13	15	13	7	11	17
Square inches of foliage consumed	111.00	0.82	1.56	0.84	0.38	1.79	5.00

[1] 2 escaped.

The washing made practically no difference in the killing effect of the lime-sulphur spray, the time of killing varying from 13 to 15 days, and the amount of foliage consumed varying from 0.82 to 1.56 square inches. In the case of arsenate of lead, however, the killing effect was considerably retarded. The length of time required to kill all the larvæ when the foliage was unwashed was 7 days; when washed 15 minutes, 11 days; when washed 30 minutes, 17 days. The amount of feeding was 0.38, 1.79, and 5 square inches, respectively.

Experiment VI.

To compare the killing effect of commercial lime-sulphur and home-boiled lime-sulphur, an experiment was conducted in which two lots of each kind were used at the strength of 1½–50. The commercial products tested 33° Baumé and the home-boiled 30° Baumé. The results are shown in Table VI.

Table VI.—*Tests of the killing effect on the fall webworm of lime-sulphur, commercial and home-boiled.*

[Experiment started Aug. 27, 1912, Benton Harbor, Mich., 20 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.				
	Lot 1 (20 larvæ)—Check (unsprayed).	Lot 2 (20 larvæ)—Commercial lime-sulphur, 1½–50.	Lot 3 (20 larvæ)—Commercial lime-sulphur, 1½–50.	Lot 4 (20 larvæ)—Home-boiled lime-sulphur, 1½–50.	Lot 5 (20 larvæ)—Home-boiled lime-sulphur, 1½–50.
Aug. 30				1	
Sept. 1		6	4	3	5
4		7	9	7	6
6		7	6	6	9
9			1	3	
19	1				
Oct. 18	5				
Total number dead	6	20	20	20	20
Number of days required to kill		9	12	12	9
Square inches of foliage consumed	116.00	1.19	1.28	3.05	4.38

It was found that the commercial and the home-boiled lime-sulphur killed all the larvæ in the same average length of time. However, the rapidity of killing was slightly greater, and the amount of foliage consumed less, where the commercial material was used, due probably to the fact that the commercial solution was somewhat stronger, which the Baumé tests would indicate.

Experiment VII.

Lime-sulphur, 1½–50, was tried out on a limited number of pear-slug larvæ (*Eriocampoides cerasi* L.), since only a few were available for this test. As in all the experiments, the insects were not placed upon the leaves until the spray had thoroughly dried. The results are shown in Table VII.

TABLE VII.—*Tests of the killing effect of lime-sulphur on the pear slug (Eriocampoides cerasi L.).*

[Experiment started Aug. 24, 1912, Benton Harbor, Mich., 6 larvæ in each lot.]

Date of examination.	Larvæ dying in each lot.		
	Lot 1 (6 larvæ)—Check (unsprayed).	Lot 2 (6 larvæ)—Lime-sulphur, 1½–50.	Lot 3 (6 larvæ)—Lime-sulphur, 1½–50.
Aug. 25		3	
26		2	4
27		1	2
28			
29			
Total number dead	0	6	6
Number of days required to kill		3	3
Square inches of foliage consumed	1.69	0.08	0.05

Three days were required to kill all the larvæ on the sprayed lots. At the end of five days, when the experiment was closed, the larvæ on the unsprayed lot were apparently in a normal condition.

MISCELLANEOUS TESTS.

Preparations were made to conduct a number of feeding experiments on the killing effect of lime-sulphur on the second brood of codling-moth larvæ (*Carpocapsa pomonella* L.). But since a sufficient number of larvæ was not obtainable, owing to the small size of this brood appearing in Michigan, no satisfactory tests could be made. Neither were there any tests with lime-sulphur alone made against this insect in the field. However, in the case of a plat of Ben Davis apples, sprayed three times with lime-sulphur, 1–50, and 10 per cent kerosene emulsion, no arsenical being used, the total percentage of windfalls and picked fruit free from the codling moth was 90.18, as against 41.31 per cent of fruit free from this insect on the unsprayed plat. Lime-sulphur, 1–50, and fish-oil soap, 7 pounds to 50, without an arsenical, in the same orchard held the codling moth to 88.19 per cent of sound fruit. The effectiveness of lime-sulphur alone in controlling the codling moth and numerous other insects will be further tested during the season of 1913.

A few laboratory tests were made of the killing effect of Bordeaux mixture, 3–4–50, on the fall webworm and about as effective results were obtained as from lime-sulphur solutions.

Self-boiled lime-sulphur, 8–8–50, the preparation used for spraying peaches in foliage, was tried against the fall webworm without any killing effect. Sulphur alone, 8–50, and lime alone, 8–50, likewise were ineffective.

CONCLUSIONS.

The foregoing tests of lime-sulphur wash against the larvæ of the fall webworm show that this preparation has decided value as a stomach poison. It is considered extremely probable that caterpillars of many species of insects, and perhaps mandibulate insects in general, will be similarly susceptible. As shown by the data given, lime-sulphur, 1½–50, while slower in killing effect than arsenate of lead, 2–50, nevertheless compares favorably with this strength of arsenical. A comparison, however, of leaf-areas eaten by larvæ subjected to lime-sulphur and arsenate of lead, respectively, shows that the lime-sulphur, especially at increased strengths, compares quite favorably with the arsenical in reducing feeding by the caterpillars.

This action of lime-sulphur as a stomach poison probably accounts for the reported practical control of the codling moth in orchards treated with lime-sulphur alone, and furnishes an additional reason for its employment as a fungicide.

Experiments in progress by the Bureau of Entomology during the past two years warrant the statement that entirely satisfactory results in controlling the codling moth in orchards may be obtained with lime-sulphur wash combined with reduced strengths of arsenate of lead.

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PAPERS ON DECIDUOUS FRUIT INSECTS AND INSECTICIDES.

THE FRUIT-TREE LEAF-ROLLER.

(*Archips argyrospila* Walk.)

By JOHN B. GILL,
Entomological Assistant.

INTRODUCTION.

Until quite recently the fruit-tree leaf-roller (*Archips argyrospila* Walk.) has been looked upon as an insect of only minor importance to cultivated crops. During the past few years, however, it has become unusually abundant and has caused considerable loss to fruit growers in certain sections, notably in Colorado and New Mexico and in New York State. The most serious outbreaks have appeared in Colorado in Fremont, Pueblo, and Montezuma Counties, and in New Mexico in San Juan and Rio Arriba Counties. The investigations, detailed in this paper, have been confined for the most part to the infestations at Canon City, Colo., and Espanola, N. Mex. In the former place the damage has been large, as the insect has appeared in serious numbers in about 1,500 acres of bearing orchards in what is locally known as the Lincoln Park section, and it is also spreading rapidly into adjacent fruit districts. If not checked the amount of loss that will be occasioned by its attacks in the future will probably be much greater than in the past. At Espanola, N. Mex., a comparatively small fruit belt, the infestation has not been so serious. The damage incurred by the leaf-roller has varied from 25 to 90 per cent of the entire fruit crop, depending on the measures of control adopted, the abundance of the "worms," and the kind or variety of fruit attacked. In unsprayed orchards the writer has seen the entire fruit crop ruined by the larvæ, and the trees completely defoliated so that not a green leaf could be noticed. When trees are so defoliated it is hardly possible for them to produce fruit buds for the following season.

In speaking of the appearance of the fruit-tree leaf-roller in New York Prof. G. W. Herrick says:

> In the spring of 1911 the larvæ of this insect appeared in enormous numbers in the orchard of Mr. W. O. Page at Bethany Center, N. Y., and to a considerable extent in neighboring orchards. Moreover, the apple leaf-roller was not confined by any means to a small and limited area, but the larvæ were found in many orchards of New York in varying numbers.

A few years ago the Missouri fruit growers suffered considerable loss on account of this same leaf-roller.

Because of the increasing economic importance of this insect the Bureau of Entomology started investigations in 1911 at Espanola, N. Mex., with which work the writer was charged, under the direction of Mr. A. L. Quaintance. During the season of 1911 little was accomplished owing to the stress of work along other lines in fruit sections that were not troubled with the leaf-roller. On account of the seriousness of the outbreak at Canon City, Colo., it was decided to maintain a temporary field station at that place during 1912 for conducting orchard spraying experiments and life-history studies of the insect. The investigations during this time have shown the value of certain practical measures for the control of this pest, and have resulted in the obtaining of considerable data on its life history. The object of the present publication is to give as much information as is now available about the leaf-roller and methods for its control.

The writer wishes especially to thank the orchardists of Colorado and New Mexico who have assisted in this work.

HISTORY.

The fruit-tree leaf-roller was first described by Walker in 1863 under the name *Retinia argyrospila*, from material collected in Georgia. In 1869 it was first recognized in this country by Robinson as doing damage, and was redescribed as a new species, *Tortrix furvana*. The following year (1870) Packard described it as a new species, naming it *Tortrix v-signatana* and giving its distribution as "Maine to Georgia and Texas and Missouri," and its food plants as black walnut, maple, cherry, and horse-chestnut. Packard also gave a description of its life history and food plants in the Fifth Report of the United States Entomological Commission, pages 192, 195, 329, 425, 530, and 655. In an article in Insect Life, Volume III, page 19, by Riley and Howard, this species is mentioned as a rose pest. Lintner included it in his Eleventh Report of the State Entomologist of New York (1896) as one of the 356 species of insects that were enemies of the apple. Gillette, in Bulletin No. 26 of the Division of Entomology, United States Department of Agriculture (1900), mentions it as a general feeder, and in the Thirteenth Annual Report of the Colorado Experiment Station (1900), page 123, it is also mentioned. In Bulletin No. 27 of the Division of Entomology (1901), page 88, Chittenden refers to it as affecting the rose. Holland, in "The Moth Book," page 422, plate 48, fig. 34, discusses this species, and it is included in Dyar's List of North American Lepidoptera, page 480, with its distribution limited to California and Colorado. In Bulletin No. 38 of the Division of Entomology, page 36, Mr. A. N. Caudell gives an account of it as infesting ash in Colorado. Horsfall,

in Bulletin No. 9 of the Missouri State Fruit Experiment Station, page 22 (1903), states that it was very destructive in 1901. In Bulletins Nos. 94, pages 9–11, and 114, page 7, of the Colorado Experiment Station, Gillette again discusses this species. The most complete account is by Stedman in Bulletin No. 71, Missouri Agricultural Experiment Station. In the last edition (1909) of "Insects of New Jersey," by Smith, it is included and mentioned as a very general feeder throughout the State. An article by Herrick appeared in the Rural New Yorker, March 2, 1912, page 263, in which it was discussed as a "new pest of the apple in New York." The same writer, in Bulletin 311 of the Cornell University Agricultural Experiment Station, gives a full account of the species, as based on its occurrence in New York State.

The above includes all the important articles on this insect, so far as the writer has been able to determine.

DISTRIBUTION.

The fruit-tree leaf-roller is generally distributed throughout the United States. Stedman, in Bulletin No. 71 of the Missouri Experiment Station, page 7, states that "this insect is found in damaging numbers practically all over the United States from Maine to the Gulf and westward to the Pacific coast and up as far as Oregon." Packard, in 1870, gave its distribution as "Maine to Oregon and Texas and Missouri." Holland gives its range as "Atlantic to Pacific." So far as the writer has been able to determine from literature on hand, the species has been definitely recorded from New York, New Jersey, Georgia, Missouri, Texas, Colorado, and California. The writer reports it in New Mexico from Espanola, Santa Fe, and Taos. It is also reported from Riverside, N. Mex. In Colorado it is recorded from Canon City, Vineland, Avondale, Cortez, Olathe, Fort Collins, Brewster, Penrose, and Garden Park. The writer has been unable to get a list of specific localities for other States.

Although widely distributed throughout the United States, it ranks as a pest at the present time in only a few localities in Colorado, New Mexico, and New York, where conditions seem to have been favorable, for some reason or other, for it to appear in enormous numbers.

FOOD PLANTS.

The insect is a very general feeder and consequently has been reported on a large number of plants. It appears at times in injurious numbers on apple, pear, plum, cherry, apricot, quince, peach, rose, currant, raspberry, and gooseberry. It has also been recorded feeding more or less on black walnut, horse-chestnut, soft maple, hickory, oak, elm, wild cherry, ash, honey locust, box-elder, sassafras,

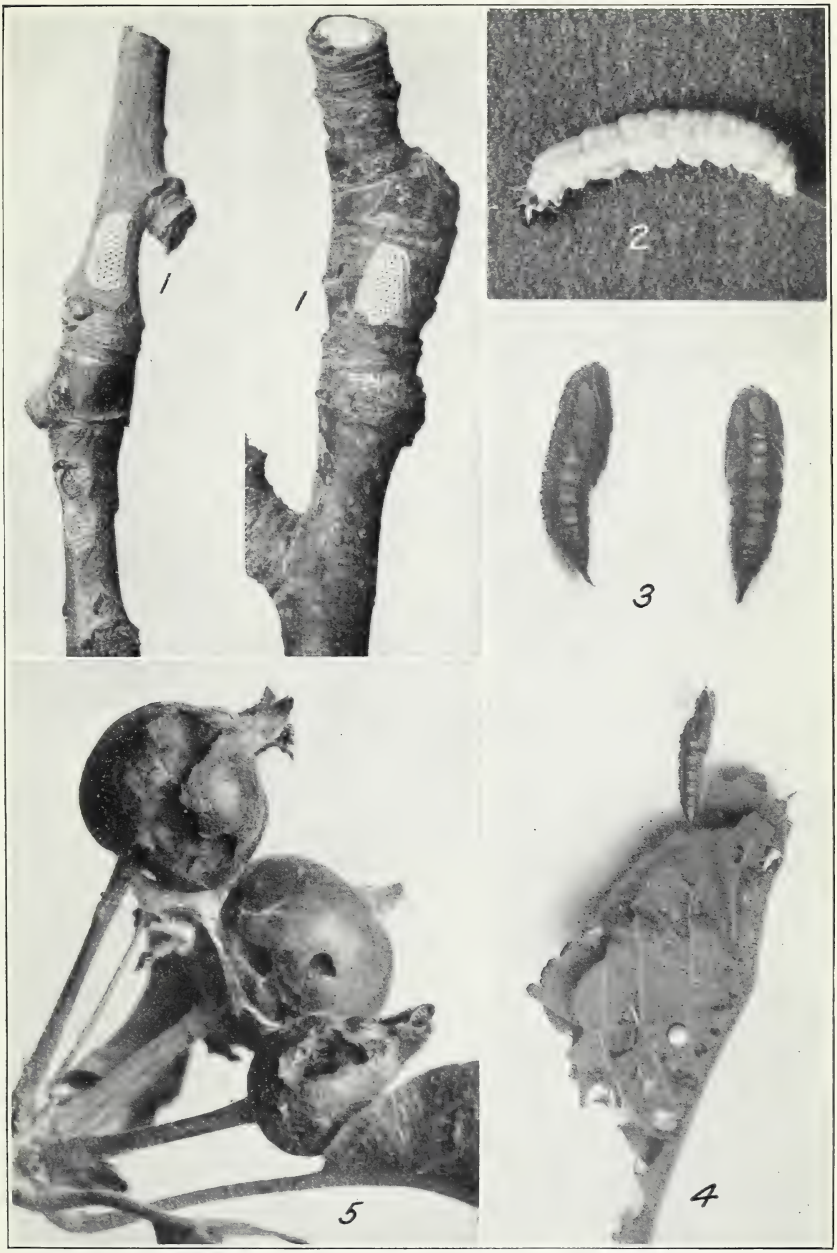
hazelnut, and osage orange. In addition to the above the writer has observed the larvæ feeding on grape, blackberry, cottonwood, Carolina poplar, basswood, cedar, lilac, Virginia creeper, snowball, hop-vines, and oats, wheat, alfalfa, red clover, onions, peas, beans, radishes, and rhubarb that were growing in or adjacent to badly infested orchards. This species appears to be able to thrive on the foliage of almost any plant.

CHARACTER OF INJURY.

As the manner in which the larvæ attack the various host plants differs to a certain degree, it seems advisable to give a rather full discussion of the more important injuries, especially those occurring on fruit trees.

In the spring, just as the buds are bursting, the larvæ begin to gnaw their way out of the eggshells and hard protective covering of the egg masses. (Pl. XII, fig. 1.) The young caterpillars at once migrate to the developing buds and begin feeding on the unfolding leaves. At first they eat small inconspicuous holes in the unfolded leaves, and at this time the average orchardist is not aware of their presence. After feeding in this manner for a few days the larvæ become quite conspicuous as they begin to spin fine silken threads from leaf to leaf. Eventually they fold or roll up a single leaf or a cluster of leaves and here they feed for the greater part of the time, though occasionally straying out of their concealment to feed in the open. (Pl. XIII, fig. 1.) Before the blossoms are fully out, or even before the cluster buds have separated, the "worms" can be observed webbing them together and feeding voraciously. Very often serious injury results before the trees come into blossom. Later in the season the webs produced by the larvæ are often quite conspicuous, as is shown in Plate XV.

As soon as the young fruit has set the larvæ cease feeding on the foliage to a large extent, and now fasten one or more leaves to the fruit and within this protection feed greedily, at first eating the skin only, but shortly consuming the pulp and the seeds or stone, depending on the kind of fruit attacked. (Pl. XIII, fig. 2.) Sometimes young apples are completely devoured except for the stem and a portion of the calyx end. Cases have been noticed where the larvæ have completely gnawed through the stems, thus causing the fruit to fall to the ground or remain suspended within the feeding nest. Damage done to apples as well as other fruits is usually so severe that the fruit can not outgrow the injury, thus causing a large percentage of unmerchantable or second-class fruit at picking time. Much fruit is also caused to fall prematurely on account of the serious injury inflicted on it when young. The writer has seen several orchards



STAGES AND WORK OF THE FRUIT-TREE LEAF-ROLLER (ARCHIPS ARGYROSPILA).

FIG. 1.—HATCHED EGG MASSES ON APPLE TWIGS. FIG. 2.—FULL-GROWN LARVA. FIG. 3.—PUPÆ. FIG. 4.—COCOON IN APPLE LEAF AND EMPTY PUPAL CASE. FIG. 5.—YOUNG APPLES INJURED BY LARVÆ. FIGS. 1, 2, 3, MUCH ENLARGED. (ORIGINAL.)

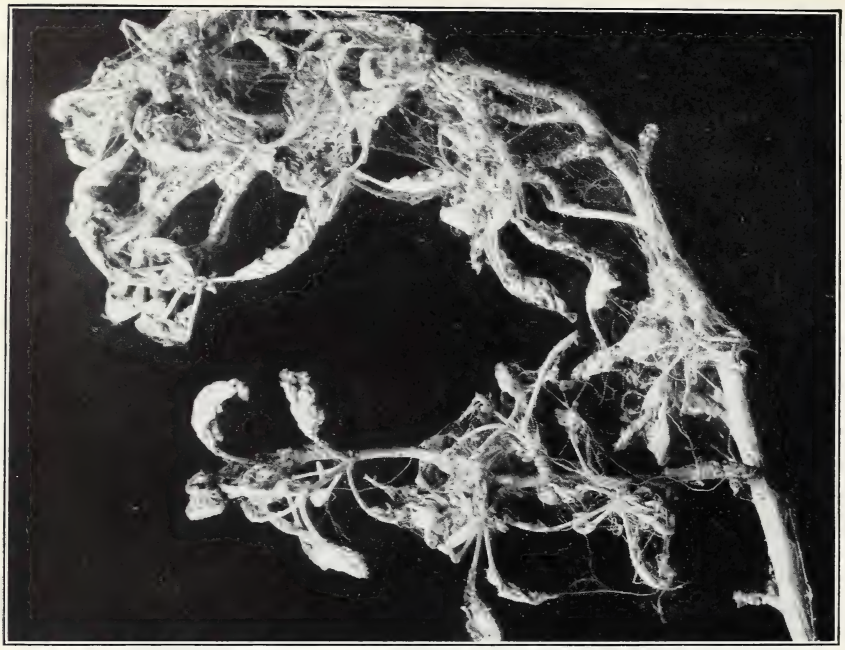


FIG. 1.—APPLE BRANCH, SHOWING WEBBING AND INJURY TO FOLIAGE BY LARVÆ. (ORIGINAL.)

FIG. 2.—APPLES INJURED BY LARVÆ. (ORIGINAL.)

WORK OF THE FRUIT-TREE LEAF-ROLLER.

APPLE ORCHARD AT CANON CITY, COLO., DEFOLIATED BY THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)

EXCESSIVE WEBBING BY LARVÆ OF THE FRUIT-TREE LEAF-ROLLER. (ORIGINAL.)

at Canon City, Colo., where the entire apple crop was absolutely ruined and where the larvæ had defoliated the trees so completely that not a green leaf could be seen. (Pl. XIV.) At Espanola, N. Mex., fully 75 per cent of the fruit crop in certain apple orchards has been destroyed by these leaf-roller "worms," which have besides caused serious injury to the foliage. Similar conditions have been seen at Vineland and Avondale, Colo.

The injury to pears is quite similar to that of the apple, but not so extensive. The writer, in talking with orchardists at Espanola, N. Mex., in reference to the amount of injury to pears that had been sprayed twice with arsenate of lead, was informed that one-fourth to one-half of the crop was damaged to such an extent that it could not be packed. Even a very slight feeding on the pear when young often results in an ill-formed specimen when mature. Pear trees are not usually defoliated by the leaf-roller, even if not sprayed. The writer has, however, observed a few instances where they were completely defoliated in a very badly infested district.

In case of stone fruits, such as plum, apricot, and cherry, much of the pulp, as well as occasionally a part of the stone, is eaten, except with the cherry, which seems to escape injury to the seed. Cherry and plum trees are sometimes entirely defoliated. According to reports from Riverside, N. Mex., during 1909 and 1910 the entire peach crop was destroyed by this pest. During the past two seasons the writer has failed to find a single instance where a peach orchard has been injured very much. The nature of the injury to the peach is a slight feeding on the surface, and the larvæ seem never to have eaten into the pulp as far as the stone.

The injury on small fruits, such as raspberries, currants, gooseberries, etc., is often quite serious, as the larvæ not only feed on the foliage but also eat into the fruits. The larvæ occasionally feed on the foliage of the grape. Of the shade and forest trees that are attacked the worst injury usually results on the elm, on which the leaves are often badly eaten. The damage noticed on truck crops, oats, wheat, alfalfa, and red clover has been a slight feeding on the leaves. The larvæ, however, on one occasion were noticed eating their way into the tops of onion plants that were growing between rows of apple trees that had been defoliated by this species. Another case at the same place was noticed where a small cedar tree was nearly stripped of its leaves by these larvæ, and the tree was covered by webs. Roses are seriously injured at times, as the larvæ not only feed on the foliage but gnaw into the flower buds and prevent their proper development.

DESCRIPTION OF STAGES.

THE ADULT.

This leaf-roller was first characterized and named in 1863 by Walker in the Catalogue of the British Museum, volume 28, page 373, as *Retinia argyrospila*. The original description is as follows:

> Female. Reddish, cinereous beneath. Head ochraceous; palpi porrect, broad, extending very little beyond the head; third joint extremely short. Abdomen cinereous, extending a little beyond the hind wings. Forewings rectangular at the tips, with several transverse slightly undulating black streaks; space along the interior border and some incomplete irregular bands silvery cinereous; costa straight, with three large silvery white marks, exterior border slightly oblique hindward. Hind wings brownish cinereous. Length of the body 3½ lines; of the wings 10 lines.
>
> a. Georgia. From Mr. Milne's collection.

The moths measure from 17 to 23 mm. across the expanded wings. The length of the body varies from 8 to 10 mm. There is a wide variation in color. The general color of the forewings varies from a light brown to a cinnamon or rusty brown. The markings on the forewings also show a variation in size, pattern, and color. Ordinarily each forewing has three whitish markings. The hind wings are without markings and are of a uniform ashy-gray color. (Pl. XVI, fig. 2, at left.)

THE EGG.

The eggs are deposited in sightly convex, oval masses or patches which vary in color from a light gray to a dark brown. The egg masses are covered by a hard protective coating. The size of the masses is variable. The average for 20 was found to be 5.1 by 2.6 mm. The average number of eggs per mass is about 90. The individual egg is quite small and is a little more than twice as long as wide. The eggs are packed in the mass very tightly. A longitudinal section of an entire egg mass presents a honeycombed arrangement. (Pl. XII, fig. 1; Pl. XVI, figs. 1, 3.)

THE LARVA.

When newly hatched the larva measures about 1.5 mm. in length and is pale yellowish green, with the head and thoracic shield dark brown or nearly black. At this time the thoracic legs are nearly black, while the prolegs are of the same general color as the body. As the larva develops the color of the head, thoracic shield, and legs gradually changes to a light brown and the body takes on a darker shade of green. Before pupating the thoracic shield and legs of the larva take on an olive-green tinge, slightly darker than the rest of the body, which is now a light green. The larva is sparingly clothed with short hairs, which arise from rather inconspicuous tubercles. The full-grown larvæ measure from 16 to 23 mm. in length and from 2 to 2.2 mm. in greatest width. The average size for 10 larvæ was found to be 20.3 by 2.04 mm. (Pl. XII, fig. 2.)

THE PUPA.

The pupa is rather variable in size. The average dimensions of 10 pupæ were found to be 10.3 by 3.1 mm. The general color of the pupa when first formed is an olive green, but later changes to a light brown and finally to a dark brown. The entire ventral surface, including the head and thoracic regions, is of a dark-brown color and the remainder of the pupa is of a much lighter brown. The wing sheaths are rather broad, extending about one-half the total length of the pupa. Just ventral to the spiracles on each side of the abdomen are two short setæ. On each abdominal segment, from the third to the last, on the ventral portion is a pronounced chitinous serrated ridge. The second abdominal segment has traces of one of these ridges. The posterior end of the pupa is supplied with a well-developed cremaster. (Pl. XII, fig. 3.)

LIFE HISTORY AND HABITS.

The life-history records were obtained at Canon City, Colo., during the season of 1912 in an open-air insectary or shelter in which glass jars were used as rearing cages. In all cases apple foliage was used as food for the larvæ.

LARVAL STAGE.

The hatching of the larvæ extended over a period of 12 days. The earliest larvæ hatched April 27 and the latest ones on May 9. As soon as the larvæ hatch from the eggs they gnaw their way through the protective covering which the females deposit over the egg masses during oviposition. The duration of the larval period showed a considerable variation. The number of days spent in the larval stage for 203 individuals is shown in the following table:

TABLE I.—*Length of larval stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Date larvæ hatched.	Number of larvæ under observation that transformed to pupæ.	Larvæ pupating in specified days from time of hatching.												
		24	25	26	27	28	29	30	31	32	33	34	35	Total number of days.
Apr. 27	21	....	....	....	....	....	....	8	5	6	1	1	....	.....
...do.....	23	....	....	....	....	....	2	7	7	3	2	1	1	.....
Apr. 29	20	....	....	....	....	1	5	7	3	2	1	1	....	.....
May 2	20	....	....	3	5	5	2	3	2	....	....	....	....	.....
May 3	23	....	2	9	4	5	2	1	....	....	....	....	....	.....
May 4	23	1	7	9	4	....	1	1	....	....	....	....	....	.....
May 7	25	2	5	8	7	2	1	....	....	....	....	....	....	.....
May 8	23	1	4	8	5	3	1	1	....	....	....	....	....	.....
May 9	25	2	5	7	5	4	1	1	....	....	....	....	....	.....
	203	6	23	44	30	20	15	29	17	11	4	3	1	5,696

Average time for all individuals, 28.05 days.

The time required for the larvæ to reach maturity was determined for 203 individuals, as is shown in Table I. The average time for all larvæ was found to be 28.05+ days, the maximum being 35 days and the minimum 24 days.

The length of the larval period for 1912 was doubtless longer than during a normal season. The weather conditions that prevailed throughout the spring of 1912 were to some degree exceptional. During the larval development from May 4 to 17, inclusive, the weather was exceptionally cool, the maximum temperatures for these days ranging from 38° to 76° F.

In the rearing cages the larvæ, when full grown, invariably transformed into pupæ in the rolled-up leaves upon which they had been feeding. In a few cases larvæ were seen pupating on the bottom of the cages. In the field larvæ usually change to pupæ in the rolled-up leaves. In a few instances they have been observed making the transformation on the bark of the trees, where no protection was afforded the pupæ.

PUPAL STAGE.

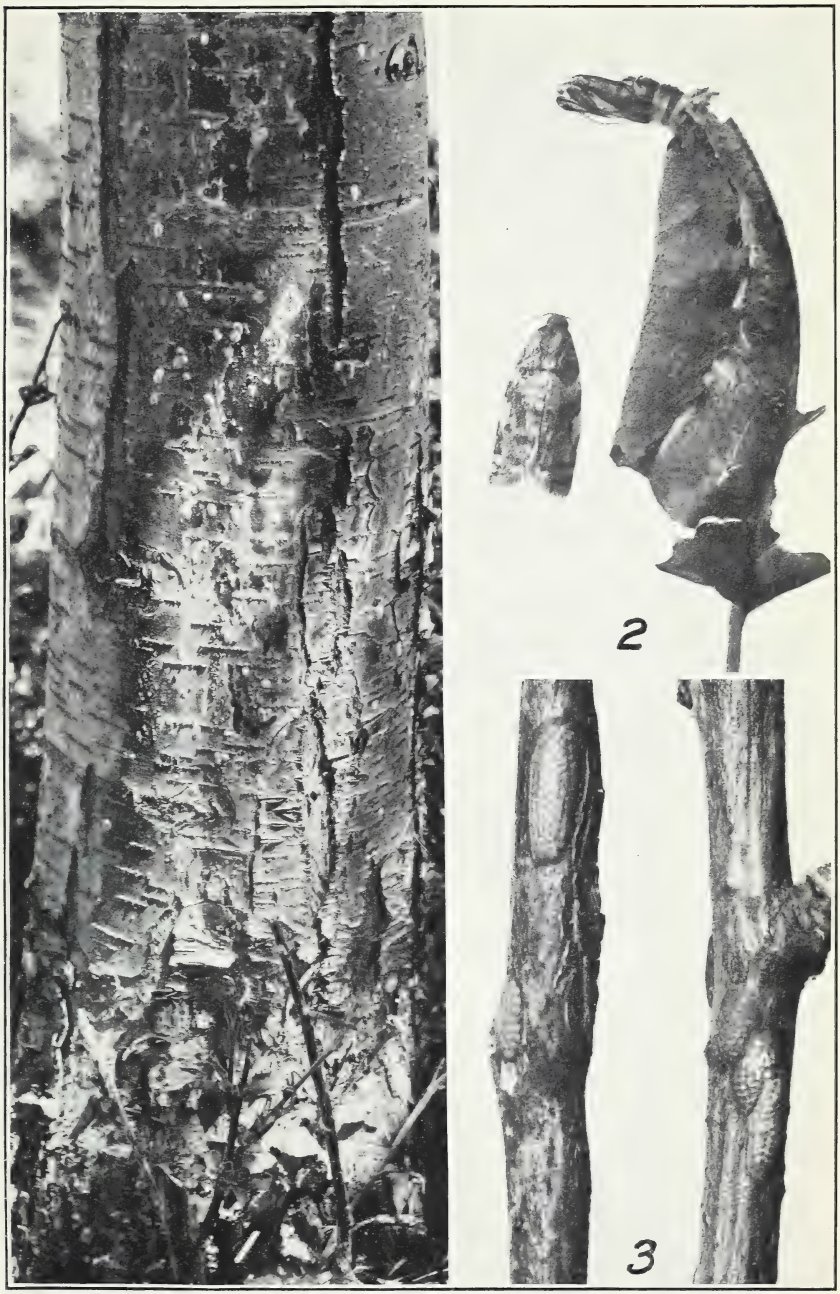
The length of the pupal period for 128 individuals is shown in the following table:

TABLE II.—*Length of pupal stage of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Date larvæ pupated.	Number of pupæ under observation from which moths emerged.	Moths emerging in specified days from date of pupation.							
		9	10	11	12	13	14	15	Total number of days.
May 28	6	....	1	4	1	....	....	....	.....
May 29	6	....	2	3	1	....	....	....	.....
May 30	17	2	2	6	5	2	....	....	.....
May 31	10	1	3	3	2	1	....	....	.....
June 1	5	....	2	1	2	....	....	....	.....
June 2	7	1	3	2	1	....	....	....	.....
June 3	18	2	3	6	5	1	1	....	.....
June 4	15	2	4	5	2	1	1	....	.....
June 5	10	....	1	1	2	3	2	1	.....
June 6	10	....	1	2	3	2	1	1	.....
June 7	2	....	....	1	....	1	....	....	.....
June 8	4	....	....	3	1	....	....	....	.....
June 9	3	....	....	2	1	....	....	....	.....
June 10	8	....	2	3	2	1	....	....	.....
June 13	7	....	3	4	....	....	....	....	.....
	128	8	27	46	28	12	5	2	1,440

Average time for all individuals, 11.25 days.

The earliest larvæ to pupate were observed on May 28, and the latest ones on June 13. The days spent in the pupal state varied from 9 to 15 days, the average for 128 individuals being 11.25 days as is shown in Table II.



STAGES OF THE FRUIT-TREE LEAF-ROLLER.

FIG. 1.—EGG MASSES ON TRUNK OF APPLE TREE. FIG. 2.—MOTH AND EXTRUDED PUPAL CASE. FIG. 3.—UNHATCHED EGG MASSES ON APPLE TWIGS. FIG. 1, MUCH REDUCED; FIGS. 2, 3, MUCH ENLARGED. (ORIGINAL.)

In the orchard the first pupæ were observed on June 1 and the maximum period of pupation was reached from about June 12 to June 20. Pupæ could, however, be found in the field as late as July 10.

Just before the emergence of the adult the pupa wriggles out of its loosely woven cocoon (Pl. XII, fig. 4; Pl. XVI, fig. 2, at right) for a short distance. The posterior end of the pupa is provided with three pairs of hooks, which are known as the cremaster, and these hooks become fastened to silken threads that have been spun by the larva on the leaf, so that the pupa is held securely, even if the greater part of the body is extended. While the writer was examining rearing cages on July 3 (8 a. m.), a pupa was noticed wriggling out of its pupation quarters.

The following observations were made:

8.20 a. m. The pupal skin or shell was cracked in the anterior region.
8.25 a. m. Moth about half out.
8.30 a. m. Moth left the pupal shell, the body being still wet and the wings quite wrinkled.
8.35 a. m. Body dry and wings straightened out and folded over back.
8.43 a. m. Wings have separated and are held roof-like over the back.
8.55 a. m. Moth crawling about in glass jar quite actively.
8.58 a. m. Observations ceased; moth was fluttering about the cage.
Total time consumed in emergence, approximately 10 minutes.

It will be noted that the time required for this moth to emerge after the breaking of the pupal skin was about 10 minutes, and inside of five minutes after emergence its body and wings were dry, but the moth did not become active until about 20 minutes had elapsed.

THE ADULT AND EGG STAGES.

From material under observation the first moth emerged on June 7 and the latest ones appeared on June 24. The maximum emergence of moths was on June 14 and 15. In the field the period during which the greatest number of moths appeared was from about June 22 to July 1. The first moth was noticed in the orchard on June 9, and by July 20 practically all moths had disappeared. From about June 25 to July 10 most egg masses were being deposited on the trees. The following egg-laying records were obtained in rearing cages, and these have a direct bearing on the length of life of the moths.

On June 21 at 8 a. m. a male and female that had emerged during the previous night were placed in a jar in which was put a small twig, so that there would be a suitable place for oviposition. The cage was examined on June 22 and both moths were quite active. On June 23 at 5 p. m. the male moth was found dead in the bottom of the jar, but the female was actively crawling about in the cage. At 8 a. m. the next day (June 24) a medium-sized egg mass was deposited on the twig. The moths were not observed copulating. The eggs

had been laid some time during the interval between 5 p. m. on June 23 and 8 a. m. on June 24. The female was dead on June 25 (8 a. m.). The female lived for about four days and the male only about two days. Eggs were deposited in two and one-half days.

On July 1 (8 a. m.) a male moth and a female moth just emerged were placed in a jar with an apple twig. Food was furnished the pair of moths by supplying them with a piece of absorbent cotton which had been saturated in a weak solution of sirup. The cage was examined the next day at 9 o'clock and both moths were quite restless. On July 3 at 8 a. m. an egg mass was found on the twig and both moths were still active. The male had died by 9 a. m. on July 4 and the female by 8 a. m. on July 5. Copulation was not observed. In this case the male lived about three days and the female about four days. The eggs were laid inside of two days after emergence of the moths.

On July 16 two moths were observed mating and at noon were put in breeding jar. The cage was again examined on July 17 and the moths had ceased copulating and were crawling over the sides of the jar. On July 18 at 4 p. m. the cage was again looked over and an egg mass was found deposited on the twig. The life of the moths could not be determined, as the time of emergence was not known. A period of about two days is shown between the time of copulation and the time of deposition of the egg mass.

There are not sufficient data bearing on the length of life of the adults to justify any generalization. The writer believes there is a wide variation in the longevity of the moths and that the females usually outlive the males. It is also reasonable to expect the moths to live for a longer period under natural conditions than is the case when they are kept in confinement. It is also likely that the females do not oviposit out of doors as readily as when confined in rearing jars with the males.

Observations under insectary conditions go to prove that the female if left unmolested during oviposition deposits all her eggs in a single mass. All egg masses deposited in rearing cages consisted of more than 100 eggs, the greatest number from one female being 140. In the orchard it is not difficult to find rather small egg masses. The smallest one observed was composed of 25 eggs. In making field observations the writer noticed that the female when ovipositing would cease the operation very readily if disturbed in any way and fly or crawl away. Ovipositing females were observed changing position when insects such as ants, ground beetles, and ladybird larvæ or adults came too near them. One species of Coccinellidæ that is especially predaceous on the green aphis of the apple was noticed several times disturbing females in the act of oviposition, compelling them to crawl or fly to another place to deposit the

remainder of their eggs. This restless habit of the females may account for the many small egg masses that are found in the orchard. The eggs are usually laid at night. Moths have, however, been seen laying eggs as early in the evening as 5.30.

SUMMARY OF LIFE HISTORY.

The larval stage in the material under observation varied from 24 to 35 days, the average being 28.05 days; the pupal stage from 9 to 15 days, the average being 11.25 days; and the adult or moth stage from 2 to 3 days for the males and 3 to 4 days for the females. The life of the moths is probably longer than this under normal conditions. Females were depositing eggs between 2 and 3 days after emergence. In the field (under Colorado conditions) the period of egg laying extended from about the second week in June to the middle of July, the maximum being reached from June 25 to July 10. The eggs remain on the trees unhatched until the following spring. Hence this insect has only one generation in the course of a year. The hatching of the eggs in the spring may extend over a period of many days, depending on the weather. The time of hatching of the eggs will vary greatly with the different seasons and in different sections of the country. Generally speaking, it may be stated that the eggs will begin hatching about the time the cluster buds of early-blooming varieties of apples are beginning to show, but before they have fully separated.

HIBERNATION.

The fruit-tree leaf-roller passes the winter in the egg stage. The eggs are deposited in masses on various parts of the host plants by females during June or July. The trunks and larger limbs or branches are often just "peppered" with them. A goodly number are also to be found on the smaller branches, twigs, and fruit spurs. Egg masses are, however, not only laid on fruit trees, but on various other plants. The writer has observed them on elm, soft maple, box-elder, currant, gooseberry, raspberry, grape, rose, lilac, and Virginia creeper. Besides the above plants, the masses have been noticed on spray tanks, on sides of buildings, and on fences. On account of the indiscriminate deposition of its eggs this insect will be found to be more difficult of control.

Observations have shown that the eggs begin hatching quite early in the spring just as the cluster buds on early blooming varieties of apples are exposed. About the time that practically all the cluster buds have fully separated nearly one-half of the eggs have hatched. On late-blooming varieties of apples, such as Rome Beauty, Jeniton, etc., the date of appearance of the larvæ is the same, although the buds are not nearly so far advanced. On Rome Beauty and Jeniton

trees it was found to be a much harder problem to do as effective spraying with arsenicals as on Jonathan, Ben Davis, Maiden Blush, and other varieties that developed their buds early. If the fruit and leaf buds are not much advanced it is very difficult to get the spray mixture where the larvæ are actually feeding. The period of hatching of the eggs may be quite prolonged, depending on climatic conditions. During the season of 1912, in the orchards, the eggs were hatching from April 20 to May 9, making a period of 19 days. It should, however, be noted that weather conditions were exceptionally cool after a short warm spell during which the eggs began to hatch. Under more favorable conditions all eggs would probably hatch inside of a week or ten days. On account of the long hatching period spraying against the larvæ was found to be very difficult.

NATURAL ENEMIES.

Several species of birds have been observed feeding upon the larvæ of the fruit-tree leaf-roller. The list is as follows: The bluebird (*Sialia sialis*), western robin (*Planesticus migratorius propinquus*), catbird (*Dumetella carolinensis*), red-winged blackbird (*Agelaius phœniceus phœniceus*), orchard oriole (*Icterus spurius*), kingbird (*Tyrannus tyrannus*), phœbe (*Sayornis phœbe*) and English sparrow (*Passer domesticus*).

The writer has reared a number of parasitic insects from the larvæ and pupæ of the leaf-roller, as follows: *Pimpla pedalis* (Cress.), *Itoplectis conquisitor* (Say), *Epiurus indigator* (Walsh), and *Meteorus archipsidis* Vier.; the latter is the same species as that reared from this host by Mr. R. W. Braucher at Bethany Center, N. Y. The following Diptera also were reared from this host: *Exorista nigripalpis* Towns., *E. pyste* Walk., *E. blanda* O. S., and *E. cheloniæ* Rond.

A few insects were found to be predaceous upon the fruit-tree leaf-roller. *Calosoma scrutator* was taken feeding on the larvæ and *Notoxus monodon* Fabr. was collected at two different times feeding on the pupæ in rolled-up leaves. *Formica montanus* Emery has also been seen attacking the larvæ and pupæ.

A small mite, which Mr. Nathan Banks considers to be a new species of Erythræus, was found feeding upon the eggs of the leaf-roller. The mites belonging to this genus are said to be always predaceous, and some of them feed on scale insects.

METHODS OF CONTROL.

During the winter of 1911–12 and the spring of 1912 many experiments were made at Espanola, N. Mex., and Canon City, Colo., against the fruit-tree leaf-roller. The experimental work will be taken up separately according to the locality in which it was conducted.

EXPERIMENTAL TESTS FOR THE DESTRUCTION OF THE EGGS.

Many laboratory tests were made for the destruction of the eggs. Only egg masses deposited on twigs were used, and these twigs were dipped in the various mixtures employed. After treatment the masses were kept in separate jars. The results of the test are shown in Table III.

TABLE III.—*Tests of sprays for the destruction of eggs of the fruit-tree leaf-roller.*

No. of experiment.	Material used.	Date of application, 1912.	Number of egg masses treated.	Number of egg masses unhatched.	Number of egg masses hatched.	Remarks.
1	Miscible oil (1:12)	Jan. 3	10	10	0	
2	Miscible oil (1:15)	...do...	10	10	0	
3	Miscible oil (1:20)	...do...	10	10	.....	
4	Miscible oil (1:10)	...do...	5	5	.....	
5	25 per cent kerosene emulsion.	...do...	10	9	1	3 eggs in mass hatched.
6	20 per cent kerosene emulsion.	...do...	10	10	0	
7	25 per cent crude petroleum emulsion.	...do...	5	5	0	
8	20 per cent crude petroleum emulsion.	...do...	5	4	1	12 eggs in mass hatched.
9	8 per cent distillate-oil emulsion.	...do...	5	5	0	
10	5 per cent distillate-oil emulsion.	...do...	5	0	5	Most all the eggs hatched.
11	Commercial lime-sulphur (1:8).	...do...	10	0	10	Practically all eggs hatched.
12	Commercial lime-sulphur (1:9).	...do...	5	0	5	Do.
13	Commercial lime-sulphur (1:10).	...do...	5	0	5	Do.
14	Commercial lime-sulphur (1:11).	...do...	5	0	5	Do.
15	Commercial lime-sulphur (1:12).	...do...	5	0	5	Do.
16	Check—untreated (caged).	...do...	5	0	5	All egg masses hatched well.
17	Miscible oil (1:12)	Mar. 5	15	15	0	
18	Miscible oil (1:15)	...do...	15	14	1	Only 1 egg hatched.
19	Miscible oil (1:18)	...do...	15	15	0	
20	25 per cent kerosene emulsion.	...do...	10	10	0	
21	20 per cent kerosene emulsion.	...do...	10	9	1	6 eggs in mass hatched.
22	25 per cent crude petroleum emulsion.	...do...	9	7	2	7 eggs in 2 masses hatched.
23	10 per cent distillate-oil emulsion.	...do...	10	10	0	
24	Check—untreated (caged).	...do...	10	0	10	All eggs hatched well.
25	Miscible oil (1:12)	Apr. 14	86	84	2	1 egg in each mass hatched.
26	Miscible oil (1:15)	...do...	122	119	3	7 eggs in 1 mass hatched; about one-fourth total eggs in 2 masses hatched.
27	Whitewash	...do...	25	0	25	Practically all eggs hatched.
28	Check—untreated (caged).	...do...	113	0	113	107 masses hatched well; about one-half total eggs hatched in 6 masses.

It will be noted that the miscible oil ranging in strength from 1:10 to 1:20 gave the best results. The crude-petroleum kerosene and 10 per cent distillate-oil emulsions ranked second in effectiveness. Commercial lime-sulphur solution was found to be ineffective, as was whitewash.

SPRAYING EXPERIMENTS FOR THE DESTRUCTION OF THE EGG MASSES.

EXPERIMENTS AT ESPANOLA, N. MEX.

The work at Espanola, N. Mex., was conducted in the apple orchard of Mr. Henry L. Pollard. The orchard consisted of 14-year-old trees in fair condition. For the spraying a barrel outfit was used and the pressure maintained ranged from about 75 to 100 pounds. The number of trees in each of the plats is shown as follows: Plat I, 21; Plat II, 22; Plat III, 14; Plat IV, 22; Plat V, 22; Plat VI, 6. The days upon which the sprays were applied were clear and quite cool. The results of the experiments are shown in the following table:

TABLE IV.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Espanola, N. Mex., 1911–12.*

Plat No.	Treatment.	Number of count trees.	Total number of egg masses observed.	Number of egg masses hatched.	Number of egg masses unhatched.	Percentage of egg masses—	
						Hatched.	Unhatched.
I	Commercial lime-sulphur solution at 1 gallon to 8 gallons water on December 14, 1911	6	265	263	2	99.24	0.76
II	Commercial lime-sulphur solution at 1 gallon to 10 gallons water on December 14, 1911	6	277	276	1	99.63	.37
III	Miscible oil at 1 gallon to 15 gallons water on December 14, 1911	6	310	21	289	6.77	93.23
IV	Commercial lime-sulphur solution at 1 gallon to 9 gallons water on Februrary 17, 1912	6	285	285	0	100.00	0
V	Commercial lime-sulphur solution at 1 gallon to 7 gallons water on Februrary 17, 1912	6	252	251	1	99.60	.40
VI	Miscible oil at 1 gallon to 12 gallons water on February 17, 1912	6	272	16	256	5.88	94.12
VII	Unsprayed	6	250	250	0	100.00	0

As will be noted, the trees sprayed with miscible oil showed good results from the spraying. The spraying of Plat III with the oil at the rate of 1 gallon to 15 gallons of water prevented 93.23 per cent of the eggs from hatching, and Plat VI, upon which the oil was used at the rate of 1 gallon to 12 gallons of water, showed a benefit of 94.12 per cent in favor of the spraying as compared with the checks. It should also be noted that all egg masses on the unsprayed trees hatched. The commercial lime-sulphur solutions gave little or no beneficial results for the treatment. On Plat IV practically all the eggs hatched, and on Plats I, II, and V there was only a benefit of 0.76, 0.37, and 0.40 per cent, respectively, from the treatment as compared with the check trees, upon which all the eggs hatched.

EXPERIMENTS AT CANON CITY, COLO.

The work at Canon City, Colo., was conducted in the orchards of Mr. E. A. Davis and Dr. Allen Bell. In the Davis orchard 14-year-old Ben Davis trees were sprayed, and in the Bell orchard the varieties treated consisted of Ben Davis, Winesap, and Colorado Orange. The trees in the Bell orchard were sprayed with miscible oil at the strengths of 1 gallon to 12 gallons of water and 1 gallon to 15 gallons of water and with 20 per cent kerosene emulsion, but unfortunately the material was not at all thoroughly applied, and no conclusions as to the efficiency of the sprays can be drawn from the results obtained. Duties elsewhere required the absence of the writer from Canon City when the applications were made. The trees in the Davis orchard, on the other hand, were thoroughly sprayed with a gasoline-power sprayer. The pressure maintained ranged from 150 to 175 pounds. At the time of the application the buds were just bursting and beginning to show the green. The results are shown in Table V.

TABLE V.—*Spraying experiments for destruction of egg masses of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Count tree No.	Total number of egg masses observed.	Number of egg masses—		Percentage of egg masses—	
				Hatched.	Unhatched.	Hatched.	Unhatched.
I	Miscible oil at 1 gallon to 15 gallons of water on April 16, 1912.	1	184	5	179	.....	.....
		2	128	4	124	.....	.....
		3	116	4	112	.....	.....
		4	135	6	129	.....	.....
		5	176	8	168	.....	.....
		6	110	6	104	.....	.....
			849	33	816	3.88	96.12
II	Check, unsprayed.....	1	155	155	0	.....	.....
		2	185	184	1	.....	.....
		3	178	178	0	.....	.....
			518	517	1	99.80	0.20

It will be noted that a comparison as to the number of egg masses that failed to hatch between the trees on Plat I, sprayed with miscible oil at the rate of 1 gallon to 15 gallons of water, and Plat II, which was left untreated, shows a benefit of 95.92 per cent in favor of the spraying.

At Canon City, Colo., no experiments were performed with lime-sulphur. The writer had, however, an opportunity to examine several orchards in this section that were sprayed with this material against the Howard scale (*Aspidiotus howardi* Ckll.). The lime-sulphur was found to be entirely ineffective in destroying the eggs of the leaf-roller.

SPRAYING EXPERIMENTS AGAINST THE LARVÆ.

The experiments against the larvæ were conducted in the Davis orchard at Canon City, Colo. This orchard consisted of many varieties, namely, Ben Davis, Missouri Pippin, Winesap, Paragon, Jeniton, Rome Beauty, Jonathan, Maiden Blush, Yellow Transparent, and Red Astrakhan. There were also a few trees of other varieties. The orchard as a whole had no more than a good one-fifth crop. On account of the light crop it was difficult to determine fairly the results of the spraying on some plats. In all cases the material was applied with a good gasoline-power outfit and a pressure ranging from 150 to 200 pounds was maintained. The plats contained trees as follows: I, 155; II, 72; III, 31; IV, 63; V, 46; VI, 38; VII, 26; VIII, 30; IX, 41; X, 6.

The results are shown in Table VI.

TABLE VI.—*Spraying experiments against the larvæ of the fruit-tree leaf-roller, Canon City, Colo., 1912.*

Plat No.	Treatment.	Percentage of injured apples.	Percentage of sound apples.	Condition of foliage.
I	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, May 2 and May 17 and 18.	20.00	80.00	Good; no arsenical injury.
II	Two applications of arsenate of lead, 3 pounds to 50 gallons of water, plus 4 ounces Paris green.	20.00	80.00	Do.
III	Two applications of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3 and 25.	15.00	85.00	Very good; no arsenical injury.
IV	One application of arsenate of lead, 3 pounds to 50 gallons water, plus 40 per cent nicotine solution (1:1,000), May 3.	15.00	85.00	Do.
V	Two applications of arsenate of zinc, 1 pound to 50 gallons water, May 11 and 25.	25.00	75.00	Fair; serious arsenical injury.
VI	One application of Paris green, 8 ounces to 50 gallons water, plus 2 pounds lime, May 4; one application of Paris green, 1 pound to 50 gallons water, plus 2 pounds lime, May 18.	18.00	82.00	Good; slightly burned by arsenical.
VII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 11.	No crop.	No crop.	Fairly good.
VIII	One application of 40 per cent nicotine solution at 1:800, plus 2 pounds of soap, May 18.	35.00	65.00	Fair.
IX	One application of 40 per cent nicotine solution at 1:1,000, plus 2 pounds of soap, May 18.	40.00	60.00	Do.
X	Check; unsprayed	98.00	2.00	Trees nearly defoliated.

NOTE.—Plats I, IV, VII, VIII, and IX were sprayed with arsenate of lead at the rate of 3 pounds to 50 gallons of water for the codling moth when the petals had dropped. Plats II and VI received the same treatment for the leaf-roller as for the first codling-moth application.

The damage to fruit was determined by making careful counts of fruits from various trees in the different plats. The total number of fruits was not counted in any case, so the percentages given are only approximate. On Plat VII there was a total crop failure.

As will be noted, the best results were obtained on Plats III and IV, where a combination of arsenate of lead (3:50) and 40 per cent nicotine solution was used. The 40 per cent nicotine solution was found to be effective only when the larvæ were quite small. It was

estimated that the tobacco mixture applied May 2 and 3 destroyed about 50 per cent of the worms then on the trees. Plat III, which received two applications of the combination spray, showed no better results than on Plat IV, which received only arsenate of lead for the second treatment. Plat VI (Paris green alone) showed a slight improvement over Plats I (arsenate of lead 3:50) and II (arsenate of lead 3:50 plus 4 ounces Paris green). Plat V, which was sprayed with arsenate of zinc at the rate of 1 pound to 50 gallons of water, gave disappointing results, as it not only failed to destroy the larvæ in goodly numbers but it seriously burned the foliage. The arsenical injury to the foliage could, however, have been prevented if lime had been added. An increased strength of this arsenical would no doubt have been more effective. On Plats VII, VIII, and IX, where 40 per cent nicotine solution alone was used, the benefit from spraying was considerably less. Plat VII of these plats gave the best results. On the day after the spraying, by carefully counting the number of dead larvæ as compared with the living ones found on the trees, it was found that about 55 per cent of the larvæ were killed by the spray. On Plats VIII and IX not more than 25 per cent of the larvæ were killed. These plats, however, were sprayed a week later than Plat VII, and the difference in results was probably due to the fact that the worms at that time were more resistant to the tobacco mixture and that it was much more difficult to reach them in the rolled-up leaves.

It will be noted in comparing the sprayed plats with the unsprayed plat as to the amount of injury to the fruit alone that there is much in favor of spraying. The benefit for each plat over the check plat is shown in percentages as follows: Plat I, 78; Plat II, 78; Plat III, 83; Plat IV, 83; Plat V, 73; Plat VI, 80; Plat VII, 73; Plat VIII, 83; Plat IX, 83. The difference in condition of foliage must not be lost sight of in determining the benefit of spraying. The check trees were practically defoliated, while the sprayed trees retained their foliage throughout the season and were enabled to develop fruit buds for the following season.

Although there is much in favor of spraying with arsenicals, alone or in combination with tobacco, they have not given entire satisfaction.

LIGHT TRAPS.

The writer had occasion to observe many lights used as traps to catch the moths of the leaf-roller at Canon City, Colo., during the season of 1912. The use of these traps was not advocated, but many orchardists were of the opinion that a decided benefit would be derived if enough lights were placed in the orchard, as the moths were very readily attracted to them. Such orchards were examined

very carefully on several occasions to see if there was any appreciable difference in the number of eggs being deposited in them and in adjacent orchards where lights were not employed. It must be stated emphatically that these traps caught vast numbers of the moths, but so far as could be determined there was little difference in the number of egg masses laid on the trees in these orchards than elsewhere in the same immediate region. Some growers, before the moths ceased flying, gave up the use of the light traps after they were convinced that there was little hope of receiving much benefit in that way. Light traps have never proven a success in controlling an injurious insect. Although some benefit may be derived, it is so slight that other means must be adopted in fighting the pest.

Orchardists have told the writer of their endeavors to get rid of the leaf-roller by crushing all egg masses that could be found on the trees. Cases are known where growers have actually hired men to go over their trees during the winter for the purpose of destroying the eggs, thinking that it was possible to control the pest by such operations. In the spring they found, much to their surprise, that the steps taken during the winter season were of little use, as the "worms" appeared, as usual, in enormous numbers on all trees. Under orchard conditions it should be distinctly understood that there is no hope of practically controlling the leaf-roller by destroying the egg masses by hand, because the masses are deposited on all parts of the trees and their small size and close resemblance to the color of the bark make their discovery difficult.

CONCLUSIONS.

The fruit-tree leaf-roller in the larval stage has been found difficult of control because of the manner in which the larvæ feed on the foliage and fruit, and also on account of the fact that they are very resistant to poison sprays. Applications of arsenicals alone and in combination with 40 per cent nicotine solution have greatly reduced the amount of injury to the fruit and foliage, but these sprays have not been so effective as is desirable.

A series of experiments for the destruction of the egg masses, conducted during the dormant season, have shown the value of mineral oils. Kerosene emulsion, crude-petroleum emulsion, and miscible oils have been tested. The last mentioned, when used at the strength commonly employed against the San Jose scale—that is, 1 gallon to 15 gallons of water—will prevent most of the eggs from hatching. From 93.23 to 96.21 per cent of the egg masses were destroyed by this material on the experimental plats. Good results also were obtained by the use of kerosene and crude-petroleum emulsions, although these substances were, on the whole, not quite equal to the

miscible oils. The ease with which sprays may be prepared from these last commend them to many orchardists although the homemade emulsions are cheaper. In preparing a kerosene or crude-petroleum emulsion care is necessary to insure a thorough and stable emulsion.

It should be stated that injury to trees treated with oils sometimes follows, although no such injury was noted in connection with the present experiments. No more spray should be used than is necessary properly to treat the tree, and the puddling of oil around the crown should be guarded against.

Lime-sulphur solutions proved to be a decided failure as a destroyer of the egg masses. Strengths ranging from 1 gallon of lime-sulphur to 7 gallons of water to 1 gallon of lime-sulphur to 10 gallons of water were sprayed on apple trees and no benefit was derived from their use.

RECOMMENDATIONS FOR CONTROL.

Experimental work has shown that the best method for controlling the fruit-tree leaf-roller is by a very thorough application of a miscible oil at the rate of 1 gallon to 15 gallons of water during the dormant season. It must be understood that by thoroughness of application is meant the use of enough material to cover all parts of the tree, from the tip of the highest or smallest branch to the very base of the trunk. In order to do thorough work the trees must necessarily be sprayed from all directions. It is very often the case that the top branches or those around the inside are missed by the man operating the rod. It must be remembered that only those egg masses actually hit or covered with the material will fail to hatch and those missed will surely hatch out "worms" in the spring to feed upon the trees. Orchardists should realize that thorough spraying with the right material and at the proper time pays well, but careless, haphazard work gives disappointing returns.

All plants upon which eggs have been laid should be sprayed. Besides fruit trees, egg masses may be found on various shade trees, shrubs, and currant, gooseberry, raspberry, and rose bushes, etc. Eggs will also be found on buildings, spray outfits, wagons, fences, etc., and it is recommended that these egg masses be crushed so far as is practicable.

The best time to spray is just before the buds burst in the spring. Late spring is preferable to early spring, as weather conditions are usually more favorable. There is also less likelihood of injury to the trees by the oil after the sap has begun to flow with considerable pressure. Spraying should not be done during threatening weather. Orchardists should bear in mind that the strength of miscible oil recommended is for a dormant spray and should never be applied to trees in foliage. Spraying should be completed in the spring before

the buds have advanced so far as to have the green tips exposed. If the above precautions are carefully followed in applying the miscible oil, danger of injury to trees will be reduced to the minimum.

There are a number of good commercial brands of miscible oil on the market. These miscible or soluble oils are so made that they mix readily with water. The material may be applied either by hand pump or gasoline-power sprayers. Power outfits are to be preferred. Nevertheless, whichever kind of outfit is employed, it is essential that it be provided with a good working agitator. To do effective work it is also necessary to have sufficiently long spray rods and leads of hose. Nozzles with medium-sized holes or apertures are recommended.

Miscible oils at the strength recommended for the destruction of the eggs of the fruit-tree leaf-roller are valuable in controlling scale insects such as the San Jose scale (*Aspidiotus perniciosus* Comst.), Howard scale (*Aspidiotus howardi* Ckll.), etc. Orchards sprayed with the oil for the leaf-rollers will not require the usual application of lime-sulphur for the San Jose or Howard scales.

In conjunction with the oil treatment in badly infested districts it is recommended that a very thorough application of arsenate of lead, at the rate of 3 pounds to 50 gallons of water, be applied when the larvæ are emerging from the eggs. The larvæ will be found to be hatching just as the cluster buds on early-blooming varieties of apple are beginning to separate. The necessity for making this application will depend largely upon the thoroughness with which the miscible oil was applied.

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